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VOL. XXVI FEBRUARY, 1935 NO. 2

The Journal of Educational Psychology

Devoted Primarily to the Scientific Study of Problems of Learning and Teaching

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$6.00 per Year • Published Monthly September to May

WARWICK & YORK, INC.

BALTIMORE, MD.

Entered as Second Class Matter Nov. 15, 1921, at the Post Office at Baltimore, Md. under the Act of March 3, 1879; additional entry as Second Class Matter at York, Pa.

THE JOURNAL OF EDUCATIONAL PSYCHOLOGY

Established 1910

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An Experimental Study of Certain Factors Affecting Transfer of Training in Arithmetic

BY JAMES ROBERT OVERMAN

An investigation of the effect of instruction on three types of examples in two-place addition upon the pupils' ability to handle closely related types in addition and subtraction, and to determine whether the amount of transfer is a function of the method of teaching. The problem was to ascertain if the amount of such transfer can be increased by helping the pupils consciously to generalize the process and to formulate, from the type taught, a general method of procedure applicable to related types.

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WARWICK AND YORK, *Publishers*, BALTIMORE, MD.

THE JOURNAL OF
EDUCATIONAL PSYCHOLOGY

Volume XXVI | February, 1935 | Number 2

A COMPARATIVE STUDY OF FACTORS IN VOCATIONAL INTEREST SCORES OF HIGH SCHOOL BOYS*

H. D. CARTER, M. K. PYLES, and E. P. BRETNALL†

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Previous studies have shown that men in any one profession have a characteristic pattern of interests, which is quite different from that of men in unrelated professions.[2,3,6] Are such clear-cut differences present at the high school level, or do the interests of boys tend to be less well differentiated? In the present study, the interrelationships of the interest scores of high school boys are considered, and the results are compared with those obtained for college students. This study of the intercorrelations of the vocational interests of boys should show whether or not there are wide individual differences in their interests, and whether the organization of the interests of high school boys is similar to that of adult males.

The Strong Vocational Interest Blank,[3] which was originally developed for use with older persons, has been used to measure the boys' vocational interests. It is often stated that ignorance of terms and lack of experience make this test more or less unsuitable for use with young persons. In view of such *a priori* criticism, there is need for empirically determining the applicability of the test. In the present study, a first attempt in this direction has been made by measurement of interests of high school boys and comparison of the results with those obtained for more mature individuals.

---

* The data for the present study were collected by H. D. Carter, in connection with his studies of twins, carried out as Social Science Research Council Fellow at Stanford University, in 1930–1932.

† The writers are indebted to Dr. H. S. Conrad, Dr. H. E. Jones, and Dr. R. C. Tryon, who read and criticised the manuscript.

A third purpose of the study is to discover, and if possible identify, any broad group factors which might make possible simplification of measurement in future research programs and in practical guidance. The statistical method used to consider such group factors is a multiple factor analysis of the intercorrelations of the interest scores. This method is used here to special advantage, since Thurstone[6] has published results of a multiple factor analysis of similar data on college men. The comparative results furnish information concerning measurement of interests at the high school level, and provide evidence of stability of results secured by the multiple factor method of analysis.

THE DATA

The Strong Vocational Interest Blank was administered to one hundred thirty-three boys in grades seven to twelve inclusive. The blanks were scored for interests known to be characteristic of men successful in each of twenty-three different occupations.

The sampling of boys in junior and senior high schools was obtained by testing all available pairs of twins in the school systems of San Jose, Palo Alto, Redwood City, and San Francisco. Both like-sexed and unlike-sexed pairs were tested; the sample of the present study, however, includes only the boys in these groups. This method of sampling seems well calculated to obtain a relatively small number of subjects selected in a suitable manner with respect to variables important in the present problem. It is true of course that an equally large sample of unrelated individuals would be a better approximation to a random sampling. In this connection, the correlation between scores of twins, which has been discussed elsewhere,[1] should be considered. Since this correlation is small, the effect must be slight. The method of securing this sampling is precisely defined, and there seems to be no evident reason why it should be unsuitable for this preliminary investigation.

The children were tested individually, or in small groups. They were allowed ample time and were given all needed instructions for filling out the blanks, an essential aspect of test administration for the very young subjects in the group. Testing was preceded by a short introductory statement of the purpose of the investigation. At that time, the children were promised a report of results, which was mailed to them later. The nature of the project, the test, and the procedure, was such that the children appeared to cooperate enthusiastically and conscientiously.

CHRONOLOGICAL AGE

The frequency distribution of the chronological ages of the boys when tested is given in Table I. The ages of the boys range from twelve to twenty years; these are years in which development is ordinarily supposed to be rapid. If there were pronounced group changes in interest scores with age, for junior and senior high school

TABLE I.—CHRONOLOGICAL AGES OF THE SUBJECTS AT THE TIME OF TESTING

AGE IN YEARS	FREQUENCY
19.0 to 19.9	3
18.0 to 18.9	6
17.0 to 17.9	29
16.0 to 16.9	31
15.0 to 15.9	28
14.0 to 14.9	21
13.0 to 13.9	11
12.0 to 12.9	4
Total No. of subjects	133

boys, the age range of this group should prove sufficiently great to reveal this fact. Hence the various vocational scores were correlated with chronological age; these coefficients are presented in Table II. As may be seen, the correlations of vocational interests with age for these subjects range from $-.11$ (r between age and the vocational interests of a journalist) to .33 (r between age and the vocational interests of a purchasing agent). The average correlation of the twenty-three vocational interests with chronological age is .06. Thus it may be concluded that the correlations of the vocational interests with age for this group do not support the idea of a systematic group change in vocational interests during the years twelve to eighteen. This finding, however, has reference only to systematic group changes in interests with age, and does not indicate whether or not the vocational interests of *individual* boys vary during this age period.

Strong[4] has noted that interest scores of high school boys tend to be much lower than those of college men, but there is no evidence that the difference results from a rapid general change in interests with age. The difference may be due largely to selective factors which affect the sampling of persons tested.

An adequate study of the development of vocational interests cannot be limited to consideration of the correlations of interest scores with age. Further treatment which seems desirable would

deal with the effects of age upon the intercorrelations between interests. The organization of vocational interests, indicated by the array of intercorrelations, is important, then, in studying the meanings of the scores. This problem has been approached in the present study by comparison of the intercorrelations determined for younger and for older subjects.

THE INTERCORRELATIONS

In Table II are given the intercorrelations of the twenty-three interest scales, for the group of one hundred thirty-three high school boys.* The range of the intercorrelations is from −.82 to .92. The high intercorrelations of certain of the scales suggest reliability of measurement, and some degree of organization of the attitudes involved. Examination of the data of Table II definitely suggests that certain groups of interests are closely related to one another, and independent of other groups. The results do not in the least suggest the disorganization which one should expect if there were no differentiation of interests among high school boys, but seem to indicate that the test is measuring several rather independent types of interests.

It is interesting to compare these intercorrelations with similar values found in the study of college men (see the table of intercorrelations published in Thurstone's article[6] based on Strong's data). The intercorrelations obtained for the college men have been compared directly with those obtained for the high school boys by correlating the two series of values. The scatter-diagram showing the relation between the results for the two groups is presented in Table III. Intercorrelations are available for only 18 of the variables for the college group; thus comparisons could be made for the intercorrelations of only these variables. As the scatter shows, the one hundred fifty-three intercorrelation values determined upon the high school group tend *in general* to agree with the one hundred fifty-three corresponding values found in the college student data. The correlation between the two sets of values is .77, evidence of a marked tendency toward agreement. The greatest discrepancies are in those correlation values

* The computations were originally carried to four decimal places. All the computations involved in the factor analysis were also carried to four decimal places. In this report, however, figures are rounded off to two places, for convenience in presentation. This procedure seems appropriate inasmuch as differences in correlation values in the third decimal place are not of practical importance.

TABLE II.—INTERCORRELATIONS OF THE TWENTY-FOUR VARIABLES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1. Advertiser	.....	.07	.61	.46	−.45	.36	−.12	−.32	.92	.83	.42	−.61	−.67	−.22	−.20	.81	−.74	−.59	−.66	−.70	.12	.18	−.52	−.08
2. Architect	.07	.....	.65	−.15	.59	.64	.70	.56	.21	.14	−.59	−.33	−.33	.65	−.02	−.18	−.15	−.56	−.42	−.43	.76	.76	−.23	.08
3. Artist	.61	.65	.....	.12	.11	.81	.39	.17	.76	.63	−.15	−.58	−.78	.29	−.28	.30	−.63	−.82	−.76	−.83	.63	.60	−.63	−.09
4. C.P.A.	.46	−.15	.12	.....	−.26	.07	−.04	−.51	.41	.53	.40	−.15	−.16	−.19	.19	.43	−.19	−.12	−.21	−.08	.01	.10	−.03	.08
5. Chemist	−.45	.59	.11	−.26	.....	.44	.83	.62	−.34	−.29	−.82	−.03	.09	.77	.17	−.61	.22	−.27	−.11	−.08	.72	.57	−.00	.13
6. Doctor	.36	.64	.81	.07	.44	.....	.68	.39	.52	.51	−.30	−.58	−.71	.41	.00	.15	−.56	−.79	−.77	−.76	.81	.66	−.61	.00
7. Engineer	−.12	.70	.39	−.04	.83	.68	.....	.64	.00	.01	−.68	−.43	−.26	.59	.34	−.25	−.21	−.54	−.50	−.38	.90	.73	−.35	.17
8. Farmer	−.32	.56	.17	−.51	.62	.39	.64	.....	−.18	−.21	−.64	−.29	−.13	.47	.14	−.31	−.02	−.33	−.21	−.18	.57	.52	−.12	.25
9. Journalist	.92	.21	.76	.41	−.34	.52	.00	−.18	.....	.89	.29	−.64	−.78	−.09	−.24	.72	−.75	−.70	−.73	−.78	.28	.34	−.55	−.11
10. Lawyer	.83	.14	.63	.53	−.29	.51	.01	−.21	.89	.....	.37	−.45	−.61	−.05	−.20	.69	−.57	−.63	−.58	−.66	.23	.26	−.33	−.00
11. Life insurance	.42	−.59	−.15	.40	−.82	−.30	−.68	−.64	.29	.37	.....	.11	−.02	−.77	.05	.68	−.14	.33	.14	.16	−.66	−.60	.09	.01
12. Minister	−.61	−.33	−.58	−.15	−.03	−.58	−.43	−.29	−.64	−.45	.11	.....	.82	.05	−.17	−.57	.90	.72	.93	.77	−.56	−.51	.83	−.06
13. Personnel	−.67	−.33	−.78	−.16	.09	−.71	−.26	−.13	−.78	−.61	−.02	.82	.....	.03	.10	−.54	.86	.75	.90	.84	−.51	−.47	.84	.08
14. Psychologist	−.22	.65	.29	−.19	.77	.41	.59	.47	−.09	−.05	−.77	.05	.03	.....	−.27	−.56	.27	−.40	−.09	−.22	.68	.71	.14	−.02
15. Purchasing agent	−.20	−.02	−.28	.19	.17	.00	.34	.14	−.24	−.20	.05	−.17	.10	−.27	.....	.10	−.05	.19	−.05	.29	.08	−.03	−.05	.33
16. Real estate	.81	−.18	.30	.43	−.61	.15	−.25	−.31	.72	.69	.68	−.57	−.54	−.56	.10	.....	−.69	−.27	−.50	−.43	−.14	−.10	−.43	.10
17. Schoolman	−.74	−.15	−.63	−.19	.22	−.56	−.21	−.02	−.75	−.57	−.14	.90	.86	.27	−.05	−.69	.....	.67	.90	.81	−.35	−.25	.91	.06
18. V.C. salesman	−.59	−.56	−.82	−.12	−.27	−.79	−.54	−.33	−.70	−.63	.33	.72	.75	−.40	.19	−.27	.67	.....	.85	.90	−.74	−.70	.65	.03
19. Y.M.C.A. secretary	−.66	−.42	−.76	−.21	−.11	−.77	−.50	−.21	−.73	−.58	.14	.93	.90	−.09	−.05	−.50	.90	.85	.....	.89	−.67	−.56	.88	.01
20. Office clerk	−.70	−.43	−.83	−.08	−.08	−.76	−.38	−.18	−.78	−.66	.16	.77	.84	−.22	.29	−.43	.81	.90	.89	.....	−.62	−.54	.77	.12
21. Physicist	.12	.76	.63	.01	.72	.81	.90	.57	.28	.23	−.66	−.56	−.51	.68	.08	−.14	−.35	−.74	−.67	−.62	.....	.91	−.46	.04
22. Mathematician	.18	.76	.60	.10	.57	.66	.73	.52	.34	.26	−.60	−.51	−.47	.71	−.03	−.10	−.25	−.70	−.56	−.54	.91	.....	−.29	.05
23. School superintendent	−.52	−.23	−.63	−.03	−.00	−.61	−.35	−.12	−.55	−.33	.09	.83	.84	.14	−.05	−.43	.91	.65	.88	.77	−.46	−.29	.....	.12
24. Chronological age	−.08	.08	−.09	.08	.13	.00	.17	.25	−.11	−.00	.01	−.06	.08	−.02	.33	.10	.06	.03	.01	.12	.04	.05	.12	

involving four scales; namely, Minister, Y.M.C.A. Secretary, Schoolman, and Personnel Worker. It is interesting to note that these are the four scales which Strong[3] found to correlate most highly with interest

TABLE III.—SCATTER-DIAGRAM SHOWING EXTENT OF AGREEMENT OF INTERCORRELATIONS OF EIGHTEEN VARIABLES WHEN DATA ON COLLEGE STUDENTS (STRONG'S INTERCORRELATIONS) ARE COMPARED WITH DATA ON HIGH SCHOOL STUDENTS (CARTER'S INTERCORRELATIONS)

r for high school students	*r* for college seniors																		
		−.90 to −.81	−.80 to −.71	−.70 to −.61	−.60 to −.51	−.50 to −.41	−.40 to −.31	−.30 to −.21	−.20 to −.11	−.10 to −.01	.00 to .09	.10 to .19	.20 to .29	.30 to .39	.40 to .49	.50 to .59	.60 to .69	.70 to .79	.80 to .89
.90 to .99																	2	2	1
.80 to .89												1	1		1	1	1		2
.70 to .79													1			2		1	
.60 to .69													1	2		1	2	3	1
.50 to .59												1	1		3		1		
.40 to .49											2	1	1	1	1		1	1	
.30 to .39							1		1				2	1	1				
.20 to .29											1	1	1		1		1		
.10 to .19					1					3	2			6					
.00 to .09							3	2	1	1			1	1					
−.10 to −.01							2	1		3	1	1	1	1					
−.20 to −.11					3	3	2	1	1	1	2	3							
−.30 to −.21				2	3	1	1	2	2	3									
−.40 to −.31				1			3				1								
−.50 to −.41					1	1		1			1	1		1					
−.60 to −.51			1	1		1	1		2		1	2		1					
−.70 to −.61			2		1	1		1	2	1	1	1							
−.80 to −.71			1		3		3	1	1										
−.90 to −.81		1																	

maturity. The most widely divergent values in the lower half of the table can be accounted for in this way. It appears that the interest scores of high school students on these four scales are less consistent in their interrelationships than are the scores on the other nineteen scales which are included in this analysis.

FIRST FACTOR ANALYSIS

The method of factor analysis[7] affords a means of reducing the complexity of results presented in a large table of intercorrelations of variables. Since the variables overlap to varying extents, it is difficult

to see how many completely independent functions have been measured. The situation is analogous to a geometrical presentation in which the coordinate axes are not perpendicular (orthogonal) to each other. Thinking in geometry is much simplified by the use of axes at right-angles. Similarly, thinking in psychology may be much simplified by dealing with uncorrelated (orthogonal) variables. This simplification may furnish a basis for further work of a practical sort in instances where the uncorrelated variables happen to be identifiable in terms of socially important concepts. There is nothing about the method to guarantee that the factors can always be identified in this way. However, if the basic data include measurements of independent variables of this practically important sort, it is likely that factor analysis will reveal those underlying functions. This is more evident when one considers the many possibilities which result from rotation of the axes. For a more complete discussion of these topics, the reader is referred to the accounts by Thurstone.[6,7]

It has been shown by Thurstone[6] that the Strong Vocational Interest Blank, when used with college seniors, measures at least four independent factors. Following his procedure[7] as outlined in 1933, a similar analysis has been carried out using interest scores of high school boys. This type of analysis indicates the number of orthogonal interest factors which must be postulated to account for the intercorrelations in Table II with reasonable exactness. This statistical technique also serves as a simplified method of summarizing the table of intercorrelations, since the relation of the different variables to the obtained factors indicates comparatively discrete or independent groups of highly related variables (see Table IV). Prolonged inspection of the intercorrelations would not give as accurate a summary of the relationships presented as do the various factor loadings. One need draw no conclusions as to the ultimate nature of the obtained factors from the analysis, since the obtained factors are only as stable as the interrelationships from which they are derived.

Table IV shows the loadings of the twenty-four variables for each of the four interest factors extracted. These loadings may also be considered as the correlations between each of the variables and the obtained factors. The first and second factors have numerous large loadings, the third has fewer, and the fourth has but one, an indication of the decreasing importance (or functioning) of the successive factors. The third factor is most heavily loaded with the interests of purchasing

agents, while the fourth is almost specific for interests of certified public accountants.

The nature of each of the obtained factors may be deduced in a general way by inspection of the variables assigned high positive and

TABLE IV.—THE FACTOR LOADINGS FOR EACH OF THE TWENTY-FOUR VARIABLES
(Computations by M. K. Pyles and E. P. Bretnall)

	The four interest factors				Sum of squares	Rank
	1	2	3	4		
1. Advertiser	−.60	.71	.13	−.21	.93	7
2. Architect	−.64	−.52	.14	.01	.70	20
3. Artist	−.87	.12	.22	.07	.83	16
4. C.P.A	−.13	.37	−.01	−.65	.57	23
5. Chemist	−.30	−.87	−.08	−.04	.85	14
6. Doctor	−.86	−.15	−.08	−.05	.78	19
7. Engineer	−.62	−.67	−.35	−.14	.97	4
8. Farmer	−.32	−.64	−.19	.28	.62	21
9. Journalist	−.72	.61	.20	−.17	.96	5
10. Lawyer	−.61	.53	.18	−.42	.86	13
11. Life insurance salesman	.32	.79	−.09	−.29	.82	18
12. Minister	.80	−.24	.42	−.13	.89	10
13. Personnel manager	.83	−.37	.16	−.17	.89	11
14. Psychologist	−.39	−.72	.45	−.09	.88	12
15. Purchasing agent	.08	−.15	−.69	−.30	.60	22
16. Real estate salesman	−.30	.79	−.25	−.23	.83	17
17. Schoolman	.73	−.53	.35	−.21	.99	3
18. Vacuum cleaner salesman	.94	−.03	−.11	−.02	.90	9
19. Y.M.C.A. secretary	.92	−.24	.30	.05	1.00	1
20. Office clerk	.92	−.25	−.09	−.17	.95	6
21. Physicist	−.83	−.53	−.10	−.10	.99	2
22. Mathematician	−.77	−.47	.11	−.16	.85	15
23. City school superintendent	.73	−.31	.38	−.37	.91	8
24. Chronological age	.03	−.16	−.29	−.21	.16	24
Mean of absolute values	.59	.45	.23	.19	.82	

negative loadings, for the four factors. Table V presents these extreme loadings. It is not easy, and only doubtfully instructive, to assign

names to the factors; yet it is apparent that, for a given factor, the variables with high positive loadings represent types of work which are commonly thought of as similar; and likewise, the variables with high

TABLE V.—THE EXTREME POSITIVE AND NEGATIVE FACTOR-LOADINGS FROM TABLE IV

Positive loadings		Negative loadings	
Factor 1			
Vacuum cleaner salesman	.94	Artist	−.87
Office clerk	.92	Doctor	−.86
Y.M.C.A. secretary	.92	Physicist	−.83
Personnel worker	.83	Mathematician	−.77
School teacher	.73	Journalist	−.72
School superintendent	.73	Architect	−.64
Factor 2			
Life insurance salesman	.79	Chemist	−.87
Real estate salesman	.79	Psychologist	−.72
Advertiser	.71	Engineer	−.67
Journalist	.61	Farmer	−.64
Lawyer	.53	Schoolman	−.53
Factor 3			
Psychologist	.45	Purchasing agent	−.69
Minister	.42	Engineer	−.35
School superintendent	.38	Real estate salesman	−.25
School man	.35	Farmer	−.19
Factor 4			
Farmer	.28	C.P.A	−.65
		Lawyer	−.42
		School superintendent	−.37
		Purchasing agent	−.30
		Life insurance	−.29

negative loadings represent somewhat similar occupations. Such seeming intra-factor consistency is the most clear-cut for Factors I and II; yet the arrangement of the factor loadings, even considering the fourth factor, evidently has some internal consistency, although its

nature is not always so apparent as to justify assigning a name to each factor.

The sums of squares of the loadings for the separate variables tend to be very high (see Table IV) when four factors are considered. This suggests that the four factors extracted can account for the intercorrelations in Table II with a fair degree of exactness. The tests were ranked according to the sums of squares of the factor loadings, to indicate which tests are more completely determined by the four factors. The more completely determined variables tend to be those which are more reliably measured (see Table VIII), but the relationship should not be perfect because specific factors which would not be included in the factor loadings would be considered in the reliability coefficients. The sum of squares of loadings is smallest (.57) for the C.P.A. scale; not only does this scale show low intercorrelations with the other scales, but its reliability is relatively low. The most completely determined variable is Y.M.C.A. Secretary, for which the sum of squares of loadings is 1.00. A number of the variables with similarly high reliability coefficients are almost equally well determined. When a variable is completely explained in terms of the factors extracted, the sum of squares of the factor loadings is 1.00. Here the sums of squares of the factor loadings tend to be high (average value .82), indicating that most of the measurement given by the twenty-three variables can be explained in terms of four independent variables.

A SECOND FACTOR ANALYSIS, AND A COMPARISON WITH RESULTS FROM A COLLEGE GROUP

To permit more direct comparison with Thurstone's results, a second factor analysis was carried out, using a table of intercorrelations of only those eighteen variables which were included in Thurstone's analysis of data on college men. Table VI presents the results of our second factor analysis. Since general comments made in considering the first analysis apply here also, the detailed consideration of factor loadings will not be repeated. It seems more instructive to consider the summary of comparative results presented in Table VII. In each of the three different analyses (Thurstone, Pyles and Bretnall, Carter), the eighteen interest variables common to the three studies were assigned loadings for each of the four factors; these loadings were ranked from highest positive (rank one) to highest negative (rank

eighteen). Correlations of the ranks of the eighteen variables, for each of the four factors in a given study, furnish an index of the independence of the four factors. Similarly, study-to-study comparison

TABLE VI.—THE FACTOR LOADINGS FOR EACH OF THE EIGHTEEN VARIABLES INCLUDED IN A SECOND FACTOR ANALYSIS (COMPUTATIONS BY H. D. CARTER)

	The four interest factors				Sum of squares	Rank
	1	2	3	4		
1. Advertiser	−.59	.73	.14	−.11	.92	6
2. Architect	−.64	−.51	.28	.05	.74	14
3. Artist	−.82	.13	.43	.16	.91	7
4. C.P.A.	−.19	.43	−.07	−.59	.58	16
5. Chemist	−.31	−.89	−.01	−.14	.90	8
6. Doctor	−.87	−.17	.13	.01	.80	12
7. Engineer	−.67	−.69	−.27	−.18	1.03	2
8. Farmer	−.34	−.65	−.10	.36	.68	15
9. Journalist	−.71	.63	.27	−.07	.98	1
10. Lawyer	−.62	.56	.22	−.32	.85	11
11. Life insurance salesman	.26	.81	−.12	−.13	.75	13
12. Minister	.84	−.22	.35	−.26	.94	5
13. Personnel manager	.82	−.36	−.03	−.31	.90	9
14. Psychologist	−.31	−.68	.47	−.14	.34	18
15. Purchasing agent	−.02	−.13	−.69	−.16	.52	17
16. Real estate salesman	−.37	.80	−.27	−.04	.85	10
17. Schoolman	.74	−.50	.23	−.32	.95	4
18. Y.M.C.A. secretary	.93	−.21	.15	−.17	.97	3
Mean of absolute values	.56	.51	.23	.20	.81	

of these ranks is one method of identifying the factors in one study with those of the other studies. Such a procedure is preferable to the crude method of inspection, for it takes account of all the factor loadings, and not merely the extremes.

Theoretically, the factors extracted from a given table of intercorrelations should be uncorrelated. Inspection of Table VII indicates that the factors do tend to be independent. In Thurstone's data, the intercorrelations of the ranks of the factor loadings range from −.12 to .40 when all four factors are considered. If the fourth factor (which is

admittedly less clear-cut) is omitted in considering the data for high school boys, the intercorrelations of the factor loadings for twenty-four variables range from −.17 to .12; and those of the loadings for eighteen variables range from −.10 to −.14. A persistent tendency toward slight negative intercorrelation may be noted, but the intercorrelations are for the most part so small that they are insignificant. It will be

TABLE VII.—INTERCORRELATIONS OF THE FACTOR LOADINGS OF THE EIGHTEEN VARIABLES WHICH WERE COMMON TO ALL THREE FACTOR STUDIES

	Adult subjects, eighteen variables (Thurstone), factors				High school boys, twenty-four variables (Pyles & Bretnall), factors				High school boys, eighteen variables (Carter), factors			
	1	2	3	4	1	2	3	4	1	2	3	4
Thurstone 1	.....	−.12	−.23	−.40	−.38	−.*82*	.03	.59	−.32	−.*83*	.24	.16
Thurstone 2	.....	.....	−.36	−.15	−.45	.38	.*65*	−.08	−.36	.40	.*77*	.04
Thurstone 3	.....	.....	.....	−.29	.*83*	−.18	.28	.03	.*87*	−.16	.02	−.38
Thurstone 4	.....	.....	.....	.....	−.10	.56	−.68	−.72	−.19	.55	−.64	−.01
Pyles and Bretnall 1	.....	.....	.....	.....	.....	−.09	.12	−.21	.*98*	−.06	−.25	−.59
Pyles and Bretnall 2	.....	.....	.....	.....	.....	.....	−.17	−.59	−.14	.*99*	−.17	.11
Pyles and Bretnall 3	.....	.....	.....	.....	.....	.....	.....	.23	.26	−.12	.*90*	−.24
Pyles and Bretnall 4	.....	.....	.....	.....	.....	.....	.....	.....	−.16	−.60	.38	.*55*
Carter 1	.....	.....	.....	.....	.....	.....	.....	.....	.....	−.10	−.10	−.60
Carter 2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	−.14	.09
Carter 3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.09
Carter 4												

noted that in each of the three analyses the fourth factor shows the least tendency to be independent. These inconsistencies suggest that the fourth factors are less adequately determined than the other three, especially in the present studies on high school boys. On the other hand, it appears that Factors 1, 2, and 3 in the two present studies are consistent, and similarly constituted in the two analyses. This similarity is encouraging, for it indicates that addition of five tests has not drastically altered the picture.

Before proceeding with discussion of the comparative results, mention should be made of the fact that the *signs* of the factor loadings are only of importance in indicating related variables. All variables which are negatively related to a given factor are as important as are those with positive sign. For a given factor, there are usually to be found a group of variables which are positively related to that factor,

and an equally important group which are negatively related to it. To use the geometrical analogy, if two factors were correlated −1.00, each would be the projection of the other through the origin; that is, they would be the same, but one would have a negative sign. Since the signs given to the factors are an arbitrary feature of the method, it is not surprising to find, in comparing the factor loadings for the high school boys with those for college men, that the negative loadings of certain of the factors found in one study are related to the positive loadings of certain factors in the other group. In this connection it is the magnitude of the correlation of factors, not the sign, which is important.

Table VII indicates that each of the three first factors tends to correlate highly with *one* of the Thurstone factors, and not to correlate with the other Thurstone factors. (Our correlation of ranks of loadings is not put forth as a perfect analytic method, but merely as a convenient improvement over mere inspection of factor loadings, for purposes of identifying the factors in the several studies.) The results are consistent in indicating that in both the analyses here, Factor 1 approximates Thurstone's Factor 3 (Interest in People*); Factor 2 is the negative of Thurstone's Factor 1 (Interest in Science); and Factor 3 is to be identified with Thurstone's Factor 2 (Interest in Language). In the first analysis here, the fourth factor is definitely related to the fourth found by Thurstone. It is interesting to note that the factor loadings obtained by Carter on the eighteen variables studied by Thurstone do not show markedly greater resemblance to the Thurstone factors than those obtained by Pyles and Bretnall on twenty-four variables. This finding suggests a somewhat greater stability of the factor loadings than might have been expected when the number of variables included is varied. Further indication of this finding is the high agreement between the factor loadings found by Carter and those found by Pyles and Bretnall.

These results may be taken as indicating that the Strong Vocational Interest Blank, when used with high school boys, tends to measure the same broad interest trends which it measures when used with adults. There is some evidence, of course, to indicate that the results are not in

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* For convenience in discussion, it seems permissible to assign to those factors the names which Thurstone[6] gave them. Thurstone has discussed the basis of this naming of factors, pointing out that it is purely inspectional; it seems fair to ask the critic to read his discussion, and to avoid attributing to these names any significance which has not been claimed for them.

exact agreement. It seems likely that the test measures the same trends, but that vocational interests in high school boys are less well crystallized than in adults, and therefore show certain differences. When used with high school boys, the Strong test apparently measures at least three (possibly four) independent variables, or interest trends.

In Table VIII are shown the reliability coefficients for twenty-one of the scales, as published by Strong;[5] these coefficients were obtained from data on college students, and are probably more suitable indications of the reliability for adults than for the high school boys. Yet it is likely that they are approximately correct for the boys, with specific exceptions which cannot be pointed out precisely until further data are secured. Table VIII also presents the sums of squares of the factor loadings for each of the three studies. Correlations of ranks have been used to indicate approximately how well these studies agree. Such results indicate that the degree to which each of the eighteen variables tends to be completely determined by the four factors is approximately the same for the two studies on high school students (rho is .83). In contrast, the sums of squares of the factor loadings obtained in these studies are not in agreement with similar values obtained in the study of adults (rho is .08 and .10 respectively). The ranks for completeness of determination, based on the sums of squares of the loadings, have been correlated with ranks for reliability of measurement, for the seventeen variables for which the necessary reliability figures are available. These correlations are .20 for Thurstone's results, .50 for the data of Pyles and Bretnall, and .64 for the results of Carter's analysis. These results might imply that specific factors, as compared with random error, are of greater significance in measurement of interests of older subjects. This possibility occurs to one in considering the fact that specific factors are not accounted for by the sums of squares of the loadings, but they do effect the reliability coefficients.* To the extent that there is specificity of measurement, reliability coefficients will tend to be higher than the sums of squares of the factor loadings.

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* In considering the results of Table VIII, the reader will note that the value of the sum of squares of loadings is in some instances greater than the value of the reliability coefficients. This calls to mind the error present in single values; the general trend is regarded as more significant. The present data are not suitable for exhaustive analysis of problems suggested by the inconsistencies of individual values in the table.

TABLE VIII.—RELIABILITY OF MEASUREMENT OF EACH OF THE INTEREST VARIABLES, AND COMPLETENESS OF DETERMINATION OF EACH BY THE FOUR FACTORS EXTRACTED

	Reliability* coefficient	Sums of squares of factor loadings		
		Thurstone	Pyles and Bretnall	Carter
1. Advertiser	.90	.76	.93	.92
2. Architect	.84	.78	.70	.74
3. Artist	.92	.82	.83	.91
3. C.P.A.	.74	.42	.57	.58
5. Chemist	.89	1.03	.85	.90
6. Doctor	.88	.69	.78	.80
7. Engineer	.94	.91	.97	1.03
8. Farmer	.88	.83	.62	.68
9. Journalist	.93	.87	.96	.98
10. Lawyer	.90	.85	.86	.85
11. Life insurance salesman	.90	.95	.82	.75
12. Minister	.92	.74	.89	.94
13. Personnel manager	.78	.63	.89	.90
14. Psychologist	.89	.89	.88	.34
15. Purchasing agent	...	.82	.60	.52
16. Real estate salesman	.90	.92	.83	.85
17. Schoolman	.90	.66	.99	.95
18. Vacuum cleaner salesman	...	....	.90	
19. Y.M.C.A. secretary	.88	1.00	1.00	.97
20. Office clerk	.89	....	.95	
21. Physicist	.94	....	.99	
22. Mathematician	.90	....	.85	
23. City school superintendent	.86	....	.91	
Mean, for seventeen variables	.88	.81	.84	.83

* The reliability coefficients are those published by Strong.[5] They were determined from data on college students and may not be perfectly accurate measures of the reliabilities of the scales when used with high school students. Reliability coefficients are thus available for seventeen of the variables common to the three factor studies.

Sums of squares of factor loadings may be compared with reliability coefficients, for seventeen of the variables. The average of the reliability coefficients is .88, and the averages of the sums of squares of loadings are: .81 for Thurstone's results; .84 for results of Pyles and Bretnall; and .83 for Carter's results. The reliability coefficient indicates the extent to which there is reliable measurement; the sums of squares of factor loadings indicate the extent to which the broad group factors extracted can account for the measurement. The difference in each case indicates the amount to be attributed to consistent measurement of a specific factor. For the three studies, these average differences are .07, .04, and .05 respectively. Considering the fact that the reliability coefficients have probable errors, and that correlation values of the magnitude of .04 to .07 have no practical importance (other than as indications of lack of relationship, lack of consistency, etc.) it appears that very little of any significance remains to be accounted for by specific factors. It may be fairly concluded that the sums of squares of factor loadings tend to be very high, in fact almost as high as the reliability coefficients. This indicates that the results of measurement which are presented in the table of intercorrelations are rather well accounted for by the four group factors extracted.

SUMMARY AND CONCLUSIONS

The Strong Vocational Interest Blank was administered to one hundred thirty-three high school boys, and the blanks were scored for interests in each of twenty-three occupations. Intercorrelations of the twenty-three scores, and the correlation of each with chronological age, were computed, and the data were analyzed by Thurstone's simplified multiple factor method.[7] Comparison was made with the results of Thurstone's similar analysis of data from college men. The intercorrelations, the results of the subsequent analysis, and the comparative findings, suggest the following tentative conclusions:

1. For the age range considered, there appears to be no systematically undirectional relationship between chronological age and the interest scores. The correlations of age with scores on the twenty-three scales range from $-.11$ to .33, and average .06. This of course does not mean that individual boys may not show constant age change in interests.

2. The intercorrelations of the interest test scores for high school boys tend to be similar to those for college seniors. The agreement between the intercorrelations obtained for college seniors and the high

school boys is indicated by an r of .77. Further analysis of specific intercorrelations suggests that the discrepancies can be attributed largely to four of the scales: namely, Minister, Y.M.C.A. Secretary, Schoolman, and Personnel Manager. These are the four scales which according to Strong's results[3] correlate most highly with his interest maturity scale.

3. Multiple factor analysis has revealed three clear-cut interest factors which the test measures when used with high school boys. When all twenty-three scales are used, a fourth factor seems to have some consistency. Apparently the test measures at least three relatively independent types of interest. However, the greater consistency of the fourth factor in Thurstone's results indicates that it apparently measures one more factor when used with adults, or at least measures a fourth factor more adequately.

4. Intercomparisons of factors found in the three studies indicate that these broad interest factors found in study of high school boys are at least in large part identifiable with those factors found in the study of adults.

5. It is evident that the relative importance of the three (possibly four) factors is not the same in the interests of adults and of high school boys. If we accept for the moment the name assigned by Thurstone to his third factor, an example can conveniently be given. *Interest in People* appears to assume a more important role in the case of the younger subjects.

6. The factor loadings assigned to the different variables in a given factor analysis tend to show very small intercorrelations. This is in harmony with the theory underlying the method, hence the fact that the fourth factor here shows moderately high correlation with another factor is taken to indicate that the fourth factor is not adequately determined. This conclusion is supported by the low agreement of the fourth factors in the two studies.

7. Finally, the conclusion may be reached that although there may be changes in any individual's vocational interests with age, the organization of these interests at the high school level is similar to that at the college level. This finding is supported by the fact that the group interest factors obtained for high school boys are identifiable with those found for college seniors.

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AN ELECTRO-CHEMICAL THEORY OF LEARNING

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An adequate understanding of learning depends upon a knowledge of its physical basis. Since the behavior of an organism arises from an interrelation between the arrangement of materials and activities within itself and within its environment, it cannot be understood from an analysis of the environment alone, but requires, in addition, an analysis of the principles of internal rearrangement.

There is a large body of knowledge concerning the internal structure and behavior of organisms, as well as a large body of knowledge concerning the external adjustment of organisms to their environment. But an adequate and reasonable theory of learning that correlates these two bodies of knowledge is lacking.

The present widely accepted hypothesis that learning is a change in synaptic resistances which are decreased by use and increased by disuse (35) is reasonable but inadequate. Physiologically it is incomplete because it fails to show how it is physically possible for general external conditions to alter the number of repetitions necessary to lower a synaptic resistance; why, in some cases, synaptic resistances appear to be unaltered after many repetitions, and in other cases greatly altered after one or two repetitions. Psychologically it is incomplete because it fails to account, among other things, for the fact that "a sense of belongingness" affects very materially the results of repetition; that as Thorndike's experiments (40) convincingly show, experiences accompanying each other repeatedly do not tend to become "connected" in memory, unless when they occur they are regarded by the learner as belonging together.

Thorndike's own hypothesis (40, p. 75) that "belonging is the consequence of direct continuity of conduction," appears not to remedy the deficiencies of the synaptic hypothesis, but to leave matters about where they stood. For if two neurones are synaptically connected they must be *directly* connected, and the lowering of the synaptic resistance between them must be (or, at least, is generally assumed to be) itself a "consequence of direct continuity of conduction."

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* Appreciation is gratefully expressed to Prof. D. P. Randall of the Department of Physics, Syracuse University, for critically reviewing the physical phases of the Electro-Chemical Theory.

Other phenomena of learning not accounted for by Thorndike's or the synaptic hypothesis include the relative effectiveness of "spaced vs. bunched drill," and of "part vs. whole learning," the fact that meaningfulness or the number of associations increases retention (*i.e.* the more inclusive the belongingness the more enduring the effect) that vividness and simplicity are also major determinants of retention, and finally, by no means least—nor last, if an exhaustive list were given—that the nature of the task, or goal, which the learner pursues determines what things shall seem to belong together and what things shall seem not to belong together.

The physical theory of learning here presented (which may be called the Closure Theory) attempts to account for all of these phenomena and, in general, to explain the types of behavior commonly known as "trial and error," "immediate insight," and "conditioned reflex." It attempts to do this with a minimum of assumptions and without reference to any physical phenomena which are neither observed nor explained.

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In addition to the known facts of neurone behavior and the known principles of electrolytic action (chiefly the principles that charges of like sign repel and of unlike sign attract each other) the Closure Theory makes use of three basic but simple assumptions. These are: 1, That neurones are in electrolytic equilibrium with their environment not only along their surface membrane but at their ends and synapses; 2, That synaptic equilibrium (as well as that at sensory and motor endings) and membrane equilibrium are interdependent; 3, That synaptic resistance, and the resistance of a neurone to being discharged, are simply aspects of the resistance that equilibrium systems in general offer to being upset—or of that type of inertia which is universally encountered in the *non-continuous* rearrangement of physical systems.

These assumptions arise directly from experimental findings, and depart very little, if at all, from conclusions quite generally accepted by physicists and physiologists. However, they cannot yet be treated as established facts.

More nearly, or quite, established are the following anatomical and physiological facts of which the Closure Theory makes use: First, there is no doubt that neurones have receiving and sending mechanisms (dendrites and axones), that the former are frequently very numerous

and the latter branched into several collaterals (3, 6, 35). It is known that neurones are in synaptic contact with one another, and that an impulse may pass from one to another (29, 35). It is known that the nerve impulse suffers no diminution as it passes from one end of a neurone to the other, but that it is slowed down—or meets resistance—at the synapse (7, 8). It is known that an individual neurone offers resistance to being discharged, and that stimuli can be summated in such a way that several closely spaced repetitions of a stimulus will cause a reaction where one or distantly spaced repetitions will not (8, 35). It is known that this summation effect is very much greater for neurones in series (in the intact organism) than for isolated nerve fibers (8). It is known that the nerve impulse in the intact organism goes in only one direction, that neurones in series have an end to end polarization, though isolated they have not (8, 34). And it is known that the nerve impulse is accompanied by (or consists in) galvanic changes along the surface membrane of the neurone—specifically, a wave of negativity going away from the stimulus (1, 8, 34). And it is fairly well established that nerve activity involves the progressive, reversible breakdown of (or leakage of ions through) the surface membrane of the neurone, which, at rest, is polarized, with the external part positive and the internal part negative (1, 7, 8, 13, 24, 27, 41).

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It will be noted that in resting nerve which is "a liquid conductor," (8) there are two polarizations; namely, transverse and longitudinal. These have been separately noted and studied, but the implications of their interrelation have not been followed up. *The Closure Theory proposes that in the interrelation between these two polarizations lies the explanation of all learning phenomena. It proposes that the fundamental change which occurs in human learning is a change in patterns of the polarization of resting neurones.*

That transverse and longitudinal polarizations are interdependent is almost a foregone conclusion. These polarizations may be referred to as "electrolytic equilibria," providing the term includes the various complex chemical actions which may be involved. Likewise the term "balances between positive and negative charges" may be used, if it is understood to include the more complex chemical balances involved in valences.

With these qualifications in mind we may describe the interdependence of transverse and longitudinal polarizations as follows:

The electrolytic equilibrium around the surface of a nerve fiber is related to the electrolytic equilibrium at its ends and synapses in such a way that when one is upset the other is also. The progressive disturbance in the surface equilibrium of the nerve fiber (the nerve impulse) results in a disturbance of the electrolytic equilibrium at the synapses, and this in turn disturbs the surface equilibrium of adjacent neurones.

More specifically, the stimulation of the end organ of a neurone results in an accumulation of positive charges at that end (1, 7, 8, 34). These charges are drawn from immediately available sources, including the surface of the neurone. The portion of the surface membrane which has been thus disturbed by the drainage of positive charges, restores its equilibrium at the expense of immediately adjoining resting portions, and this continues as a wave of disturbance—or negativity—and of restoration and reestablishment of the surface polarization. When the electrolytic swirl reaches the other end of the neurone, the equilibrium of the synapse is upset, and a similar swirl of readjustment passes on along the surfaces of adjoining neurones.

Why such disturbances sometimes leave permanent changes in the equilibria between neurones and sometimes do not, why they do not spread indefinitely, why they sometimes follow some paths and not others, are questions which the Closure Theory must attempt to answer.

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We may turn first to a consideration of the question of permanence. Put differently, this question is, why do some neurological disturbances leave definite engrams whereas others leave no distinguishable trace? The answer which the Closure Theory proposes to this question is, briefly, that *the endurance of any electrolytic pattern is dependent upon* 1, *its closure;* 2, *its cohesiveness;* and 3, *its completeness.*

1. By *closure* is meant a physically closed equilibrium system. Any self-sustaining equilibrium system may be included in the definition. For example, three magnets arranged as in Fig. 1 will not "lose their magnetism" because the equilibrium pattern is closed and hence self-sustaining. But three magnets arranged as in Fig. II *will* "lose their magnetism" (being subjected to external stray fields or "shocks") because the equilibrium pattern is open and hence cannot sustain itself.

Cerebral closures are formed by the simultaneous and successive discharge of neurones in such a pattern that a complete circuit of

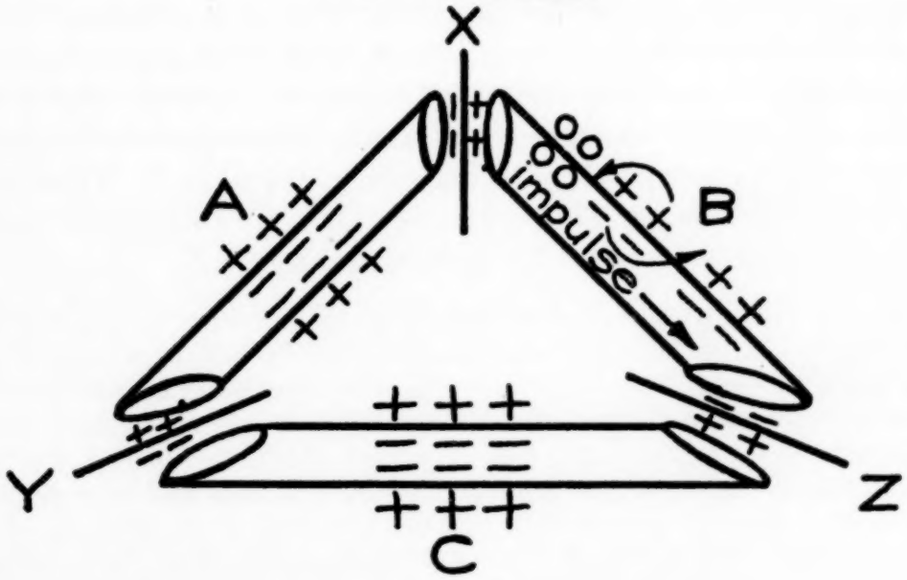
related activity and adjustment is formed. Such a circuit is diagrammed in Fig. III.

In this figure, three nerve fibers, *A*, *B*, and *C* are represented as cylinders surrounded by a membrane which is externally positive (+) and internally negative (−). The fibers are polarized at their ends

FIG. I FIG. II

(Synapses *X*, *Y*, and *Z*) in such a way that any disturbance will follow the direction of the straight arrow in neurone *B*. The curved arrows in neurone *B* indicate the nature of the swirl of membrane readjustment which constitutes the nerve impulse.

FIG. III



The significance of Fig. III will appear if it is borne in mind that the disturbance of equilibrium here represented may arise from the withdrawal as well as addition of charges at a synapse. Thus, if the two negative charges of *C* are removed at synapse *Y* there will be a kind of

backward action in *A* until the positive ions from *Y* have found equilibrium on the surface (or in the membrane). This will involve the two negative charges of *A* at *X*. And this in turn will release the two positive charges of *B* at *X*, and a similar backward (recovery) action will take place in *B*. This will continue around the circuit, reducing the magnet-like (or valence-like) synaptic connections all along the path. But this evidently will not occur so long as the circuit is complete, as shown in Fig. III, and is not cut across by conflicting equilibrium patterns.

In brief, our neurological pattern closely resembles the analogous pattern of magnets in Fig. I in point of enduring when closed, and fading when open. It also closely resembles chemical compounds whose stability is greater when the number of satisfied valences is greater.*

The foregoing discussion indicates two major points which will be further supported by the detailed account that follows. These are:

(*a*) *Following the simultaneous (or closely successive) discharge of several neurones, a new electrolytic equilibrium is set up at their synapses;*

(*b*) *This new equilibrium is maintained in the case of a "closed" pattern, but not in the case of an open pattern.*

These two characteristics of neurone behavior are sufficient to account for the fact that repetition must be accompanied by a sense of belongingness in order to the effective. For it is proposed *that psychologically cerebral closure is experienced, on the level of consciousness, as "belongingness"* or *"Zugehörigkeit";* that is, factors which affect, activate, and support the same or mutually dependent cerebral closure systems are experienced as "belonging together." Therefore, *to say that closure is essential to the preservation of any engram is equivalent to saying that "belongingness" is essential to any recall.*

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* Note the parallel between the foregoing description of a closed circuit of neural activity and the following description of the subjective experience of perception as given by Odgen (31, p. 127). "Therefore instead of defining perception as a complex of sensory experience and associated imagery, we have defined it more broadly as the experience of a closed circuit of events. Indeed, it is because of this "closure" that we give heed to a series of events and thus perceive it. The dynamic nature of the circuit is indicated by a real or quasi beginning, and a real or quasi end. The notion of a circuit is appropriate, because the end completes the process."

Numerous writers have sensed the correspondence between such psychological phenomena and universal electro-physical phenomena. As long ago as 1907, C. L. Herrick wrote (11, p. 219) that "consciousness seems to require equilibrated energy as a condition of its unity." And (p. 213) that "consciousness is not unrelated to gravitation, but is part of the same universe of activity."

2. The second factor upon which the preservation of an engram depends is *cohesiveness*, which we may define as, physically, the degree of resistance which any closed equilibrium pattern (of given completeness) offers to disturbance. Thus in a pattern of magnets, "cohesiveness" is determined by the intensity of magnetization of the pieces making up the pattern.

In a cerebral closure pattern, cohesiveness depends largely upon the number of charges of opposite sign in equilibrium at the synapses, and upon the simplicity of their arrangement and "harmonics."

The number of charges at the synapse will obviously depend upon the frequency, intensity, and duration with which the neurones in a system are discharged. That greater numbers of charges exert more "pull" upon each other than smaller numbers is an established physical fact. It is equally well established that (other things being equal) more complex equilibrium systems are more readily disrupted than less complex equilibrium systems.

The word "harmonics" is here employed to indicate a certain kind of complexity. Charges may be carried by ions or molecules of widely different complexity, and their satisfaction or equilibration may involve chemical changes of widely different extent—from the formation of a simple double electrical layer (37) to the formation of stable and complex compounds. The extent of chemical and electrolytic action involved in the equilibration of charge carriers of various complexities and various degrees of availability is referred to as the "harmonics" of an equilibrium system.*

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* Symonds (37) following Troland (41) suggests that two of the principle charge carriers are hydrogen ions and carbonate ions, for "the liquid of the nerve fiber is shown to include carbonic acid . . . which, in solution . . . tends to ionize as indicated by the formula: $H_2SO_3 \rightleftarrows H^+ + HCO_3^-$."

Johnson (17) also assigns a major rôle to the hydrogen ion, because of its relative speed and extremely small size. He speculates on the function of the cell body in relation to the ionic activities along its surface as follows: "Such membranes make it possible for the cell to take from its environment . . . certain substances which are synthesized within the cell, and possibly within specific intracellular reticules, to form compounds which are not present in equally high concentrations, if indeed they be present at all, in the surrounding fluids. Thus the cell may be said, figuratively, to contain a number of special chemical laboratories, each of which manufactures a restricted number of products, and stores them in special reservoirs for consumption upon demand. . . .

"There is reason for believing, as a matter of fact, that some of the products synthesized are long carbon chain compounds, extremely unstable, and capable of disruption at explosive speeds, when the electromotive forces in their vicinity are suddenly altered."

Relative cohesiveness, as will be shown subsequently, determines the degree to which groups of neurones tend to act as a unit; and this, it is proposed, corresponds with the simplicity, stability, and automaticity of behavior patterns. In other words, increase in the relative cohesiveness of cerebral closure patterns corresponds with the changes in behavior or consciousness that follows drill or the *repetition of experience.*

3. The third factor upon which the preservation of an engram depends is *completeness,* and this is defined as physically the degree to which an equilibrium system is supported by surrounding systems or its environment, on the one hand, and by involved systems or its own development, implications, and internal elaborations, on the other hand.

Completeness of a cerebral closure pattern depends largely upon how many of the branches of its involved neurones have their "valences" satisfied within the system or within supporting systems.

The term "valence" is borrowed from chemistry because of the close analogy between the behavior of chemical equilibrium patterns and cerebral equilibrium patterns. Thus in H_2O all the valences are satisfied within the system; in H_2O_2 the system supports an unsatisfied valence. Likewise, the members of a closed neurone pattern may, while sustaining an equilibrium among themselves, fail to establish a self-sustaining equilibrium at the synaptic connections of their branches.

Expressed differently, *the degree of "completeness" of a closure system means the extent to which it is integrated with its environment and organized within itself;* and this, it is proposed, corresponds to the degree of adequacy, logic, and coordination of behavior. In other words, an increase in the degree of completeness of neural patterns corresponds to the change in behavior or consciousness that follows observation and reason, or the *extension of experience.*

. . . . . .

We have so far attempted to answer the question: Why are the results of some neural disturbances more permanent than the results of others? We may now turn to the question: Why do not disturbances spread indefinitely among all the neurones, instead of following more or less definite paths of limited extent?

If the obvious answer is proposed that nothing spreads indefinitely or indifferently, but that any movement or impulse, whatever its

nature, follows some channel of least resistance and is limited in extent, then we must ask further: *What determines the configuration of channels of least resistance in the cerebral cortex, and the extent to which cerebral disturbances may spread?*

The importance of this question in a discussion of learning will be recognized if it is conceded that *new modes of behavior are due to new combinations of cerebral neurones acting as units in transmitting disturbances which arise from changes in the condition of the organism and its environment.*

The difference between the foregoing concept and the concept of reflex arcs should be noted. According to the view here expressed, the overt behavior of an organism does not arise directly from a stimulus, but from the combined activity of great numbers of neural units. The combination is determined by the environmental and organismic conditions of the moment, and by the shape, condition, and activity of the units so combined. These units may or may not change their shape or condition as they enter into new combinations with each other. *In so far as they do change in such a way as to become more firm (cohesive) and more easily related to each other (complete) under the conditions laid down by the nature of the organism and its environment, learning takes place.*

From this viewpoint, neural units may be compared to building blocks, and adjustment to the environment may be compared to the combining of these blocks into various structures. *Learning, then, corresponds to changes in the building material of such a nature that the units are stronger and fit more readily into useful structures.**

The tendency of connected neurones to act as a unit depends (apart from structure which may be set aside as a constant) upon the relative height (relative to each other and to other connections) of their synaptic resistances.

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* Gerard says (8) "Learning . . . appears to depend upon some kind of mass integration of the activity of large numbers of neurones; and, of course, all normal subjective experience indicates a unity which is apparently inexplicable in terms of separate impulses rushing along inumerable fibers from cell to cell of the brain."

And Lashley (25, p. 21) says "The nervous unit of organization in behavior is not the reflex arc, but the mechanism whatever be its nature, by which a reaction to a ratio of excitation is brought about."

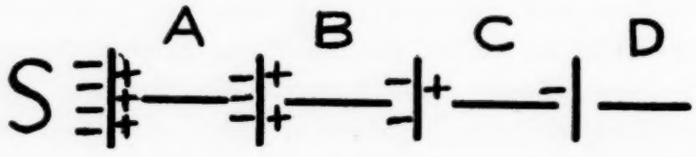
Also Von Kries (42) is quoted by Koffka (21) as saying, "In many ways learning cannot be a matter of the development of pathways which bring remote parts into connection, but must be something that can only be pictured as the formation of unified domains, facilitating the coexistence of various states."

The height of a synaptic resistance depends upon the number of partially engaged charges of opposite sign (on either side of the synapse) composing the synaptic equilibrium and upon the harmonics of the equilibrium system. The more interdependent the harmonics and the larger the number of partially engaged charges the lower the synaptic resistance.

The term "partially" as applied to charges "engaging" each other across a resistant synapse implies simply that these charges are still free to be engaged by charges of opposite sign on their own side of the synapse. An illustration of this type of physical relationship may again be seen in the behavior of magnets. If a bit of steel is held by magnet *A* through, say, a sheet of cardboard, it is "partially" engaged, because another magnet *B*, with a strength equal to *A*, but on the same side of the sheet of cardboard as the bit of steel, may engage it despite magnet *A*.

It is precisely this principle which accounts for the disappearance of traces left by open patterns of disturbance, such as that shown in Fig. IV.

FIG. IV



In this figure, a stimulus, *S*, is represented as being equivalent to four negative charges, and the resistance of each synapse (or vertical line) is represented as equivalent to a loss of one charge. The resistance offered by the membrane equilibrium of each neurone is likewise represented as equivalent to one charge—that is, it takes more than one charge to upset the membrane equilibrium and thereby "discharge" the neurone.

Under these conditions, the disturbance propograted by *S* in Fig. IV will diminish* until it reaches neurone *C*, which will not be discharged, but will be in a state of readiness, because of the fact that the displacement of only one more charge is required to set it off.

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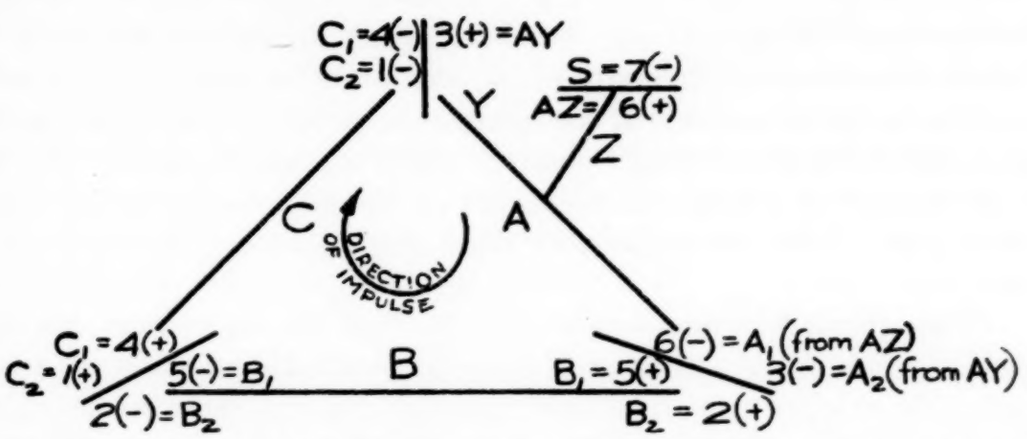
* Childs (4, p. 224) points out that because of physiological gradients and synaptic resistances, "The all or none type of reaction does not exclude the possibility of conduction with a decrement and of a limited range or distance."

When S is *removed* it will release three positive charges in A, and these in readjusting will satisfy the three partially engaged negative charges in A, thereby releasing the two positive charges in B; and so on, until all the additional charges which S has produced at the synapses have been eliminated. In other words, recovery in an unclosed disturbance pattern results in equalizing the additional charges on either side of the synapses by reducing them to zero.

In a closed pattern, such as that shown in Fig. V, recovery also results in equalization of additional charges at the synapses, but not in reducing them to zreo.

FIG. V



In Fig. V $A_1 - B_1 - C_1$ indicate number of charges freed by the initial impulse arising from S. $A_2 - B_2 - C_2$ indicate number of charges freed by "freed-back" impulse arising from C_1.

In this figure the same assumptions are made as in Fig. IV, except that the stimulus is stronger and the circuit is completed. In order to complete the circuit as simply as possible, neurone A is represented as having two dendrites, Y and Z. Dendrite Z is represented as receiving a stimulus strong enough to disengage from the membrane, and attract to the point of stimulation, six positive charges; this results in the freeing of six negative charges at the other end of A, and the attraction to the synapse* of five positive charges of B, and so on around until dendrite Y is reached; here three $(+)$ charges are attracted, releasing three more $(-)$ charges at the synapse of A with B, which engage two more positive charges in B, and so on around a second time, A_2, B_2, C_2, (this second circuit will be called the "feed-back") until the number of

* Synapses, it should be noted, act as electrical condensers.

charges attracted to a synapse are not enough (due to losses caused by synaptic resistances) to discharge an adjacent neurone, which is the case when C_2 reaches Y. Thus when the impulse has run itself out, we have at the synapses additional charges in the amounts shown in Fig. V.

When S is removed, a recovery action will be started by the resultant release and readjustment of the six positive charges in Z. These six charges will satisfy all but three of the negative charges in A at its synapse with B, thus releasing all but three charges on the other side of the synapse, and so on around until, at the end of recovery, there will be, as the result of stimulation, three additional charges on each side of all the synapses.

It should be borne in mind that there is no synaptic loss in recovery, because—according to our postulation—synaptic resistance is a resistance to an upset in equilibrium, and is not of such a nature as to cause a charge on one side of the synapse to "let go" of a charge on the other side, unless a stronger counter claim is made upon it. On the other hand, it is assumed that charges on the same side of the synapse have more "hold" on each other than charges on opposite sides of a synapse.

From the foregoing it may be seen that the more complex the figure, the greater the number of charges required to produce the feed-back. In other words, feed-back depends upon a ratio between the simplicity of the figure and the intensity, duration, or repetition of stimulation. These facts correspond to the psychological fact that to learn a complex figure is more difficult than to learn a simple figure—that to insure retention longer exposure, more repetition, or greater vividness is required.

It may be that, as the phenomena of "chronaxie" (8, 23, 31) seem to indicate, the *equalization* of charges on either side of a synapse is quite as important as their *accumulation*. It is probably true that an uninterrupted series of connected neurones which have equivalent number of charges and equivalent harmonics at the synapses between them tend to act as a unit more readily (*i.e.* with the support of less complicated stimulus patterns) than similar connected series which contain more unequal synaptic resistances and harmonics. But whether this proposal is accepted, or merely the more obvious fact of charge accumulation is accepted, it is clear that *alteration of synaptic resistances occurs as a result of rest (recovery of equilibrium) following a closed pattern of neural disturbance.*

The fact that the tendency of neurones to act as a unit is the result of *recovery* following activation of those neurones in a closed pattern helps to explain the outcome of experiments in "spaced vs. bunched" drill (36) and "part vs. whole" learning (33); and suggests experiments, postulated on the Closure Theory, to determine the relationship between the factors in $\frac{\text{whole}}{\text{part}} : \frac{\text{spaced}}{\text{bunched}}$ repetitions, and to discover the effects of different types of rest between drill periods.

The *number* of additional charges left at the synapses of a closure system depends upon the *frequency*, *duration*, and *relative intensity* (vividness) with which the system has been activated, and determines the resistance of the system (or unit) to disruption as well as the degree, extent, and duration of stimulation necessary to activate it. Recency is important in that the longer a lapse of time the greater the possibility of a unit's being disrupted or altered by conflicting systems, (*i.e.* of retroactive inhibition).

These facts help to explain the observed relationship between the "strength of a connection" (or the stability of an acquired response pattern) and the frequency, vividness, and recency of the situation giving rise to that connection.

. . . . . .

A major problem that must be answered by any adequate theory of learning is: *What governs associative groupings?* In the present discussion this question becomes:

1. What determines whether a pattern shall be closed or open?
2. What determines the *form* of closure?

The answer to the first question is simply that closure is due in general to a number of stimuli acting simultaneously or in sequence in such a relationship that their disturbances cross. In other words, *a closure is a structure of cross-irradiations of disturbances.**

This directly suggests the answer to the second question. For if closure is due to the cross-irradiations of disturbances, the form of closure will be determined by the relative intensity and nearness (in time and space) of stimuli. If several weak stimuli are near enough together (and there is no interference from competing stimuli) their disturbances will cross, and they will become unified or part of the same

* This, and one or two other points appear to be in line with Kohler's (18) theory of traces, a work with which the writer was not acquainted when he first presented the Closure theory in outline before Sec. I, *Americ. Assoc. Adv. Science*, in June, 1932.

closure. If they are more separated, their disturbances will not cross and they will not be included in the same closure. If, however, at their increased distance (in time or space) their intensity is increased to the extent that fading will not take place before the impulses cross, they will once more be included in the same closure system—psychologically they will seem to "belong" together.

According to this view, then, temporal separation (t), spatial separation (s) and intensity (i) of excitation are so related to the unification of excitation (When $\frac{ti}{s} = 1$) that Cortes laws (22, 44) are a necessary corollary. His findings that temporal interval and intensity vary inversely with each other and directly with spatial separation are precisely what would be predicted on the basis of the physical explanation of closure here outlined. This explanation is, indeed, sufficient to account for all of the characteristics of the Phi Phenomenon.*

In addition to the external factors (t, i, and s) governing the form of any closure, there are internal factors, which may be grouped roughly under the three headings, structure (c), action (a), and need (n).

"*Structure,*" as used here, means all organismic compositions and arrangements (including engrams) which complicate, obstruct, or facilitate the formation of closures.

"*Action*" means all spontaneous activity—*i.e.* activity arising predominantly from within the acting "agent," as in growth—or *that part of re-action which goes beyond the adjustment of the organism to the environment and establishes the conditions for the adjustment of the environment to the organism.*

"*Need*" means all conditions of disequilibrium resulting from an unbridged gap between areas of high and low potential, within the organism.†

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* It seems, moreover, to describe the wanted mechanism—referred to by Lashley (25) as quoted in an earlier footnote—"by which a reaction to a *ratio* of excitation is brought about."

† Gerard (8, p. 78) points out that, "It is not yet known what type of mechanism, aside from the passage of nerve impulses, may be held responsible for [learning] phenomena, but the possibility certainly exists that regional potential changes enter into it. It will be recalled that an active cell develops a negative potential in relation to resting regions. . . . Also the sensitivity to stimulation and the type of response of a nerve fiber can be modified by passing electric currents through it, quite aside from their ability to excite it directly (2) . . . It will be seen that the activity of a large number of cells at approximately the same time would produce potential changes of a whole region which in turn might modify the sensitivity of other cells and tend to bring the entire group into synchrony."

When the ratio between the external factors, *t*, *i*, *s*, and the internal factors, *c*, *a*, *n*, is such that the external factors predominate, the psychological experience, on the level of consciousness, is probably that of relatively passive *observing* and perception. When the reverse is the case the corresponding experience is probably that of relatively active seeking and selection (or the analysis and recombination of stimuli).

Likewise, on the level of consciousness, a cerebral area of high potential may be experienced as the acting "*agent*" (*e.g.* one's self) and an area of low potential, which is sufficiently stable and localized to determine the general direction of equilibrative activity, is often experienced as a "*goal*," *i.e., a patterned gap in perception toward which the agent moves.** Accordingly these terms may be adopted as convenient lables for the electro-magnetic conditions depicted in Fig. VI.

When an agent-goal relationship has been established, external stimuli are experienced, on the level of consciousness, as (1) cues, (2) obstacles, (3) satisfiers, and (4) neutral background. Corresponding factors in cerebral closure may be defined as follows:

A "cue"† is any stimulus pattern which releases charges that facilitate (*i.e.* provide paths of least resistance for) the passage of current between areas of high and low potential.

An "obstacle" is any stimulus pattern which releases charges that deflect or block the direct passage of current between areas of high and low potential.

A "satisfier" is any stimulus pattern which releases the charges necessary to bridge a gap (or complete the "circuit") between "agent" and "goal"—in other words, to equilibrate areas of high and low potential.‡

Cues and satisfiers it will be noted both furnish paths of least resistance. The difference between them is simply that whereas the

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* Compare with Wheelers definition of a goal (44, p. 545) as "a point in an energy system toward which a body moves under stress."

† In order to indicate the adequacy of the Closure Theory to resolve some of the conflicts between various psychological viewpoints, an effort has been made, throughout the present discussion, to employ terms characteristic of different schools of thought. For example, "cue," "redintegration," "telescoping," etc. have been borrowed from Hollingworth; "satisfier," "associative shifting," "trial and error," etc. from Thorndike; and "goal," "insight," "closure," etc. from the Gestalt Psychologists.

‡ An *anticipated* satisfier, is, until it is actually experienced, identical with the goal providing it is not held in mind as one of several possibilities.

disturbance arising from the satisfier completes the circuit, that arising from the cue merely leaves a trail of free charges that may readily become part of the circuit *after* the occurrence of a succeeding stimulus.

Such a trail (1) results from the onset and *removal* of the cue stimulus, and (2) must be open or relatively incomplete.

Although it has never been remarked (to the writer's knowledge) that the *removal* of a stimulus creates a temporary surplus of free positive charges, this conclusion necessarily follows the demonstrated fact that the *onset* of a stimulus creates a temporary surplus (wave) of free negative charges. For, if negative charges are freed by the engagement of positive charges at receptor end-organs, and, being freed, are immediately re-engaged by nearby positive charges, thereby releasing other negative charges which in turn are re-engaged, and so on, *away* from the point of stimulation, then the *disengagement* of positive charges at receptor end organs, will leave a temporary surplus of positive charges at that end of the neurone tract as well as a temporary surplus of negative charges at the other end.

If the two ends of the tract do not come together in a *closure*—that is, if the disturbance pattern is relatively incomplete—there will be a high potential at one end and a low potential at the other. This constitutes a path of low resistance. More specifically, it constitutes a "free valance" area—an area ready to attach, or become attached to, some other area. For, positive and negative charges released by the onset and removal of *subsequent* stimuli, (affecting nearby areas) will either attract or be attracted by the already accumulated free charges of opposite sign. Whichever accumulation (that arising from succeeding or preceding stimuli) is greater and more concentrated will, of course, exert the greater attractive or repulsive force.*

From the foregoing it is clear that *intermittency*, and *sequence of stimuli*, and the *relative intensity* of (successive as well as simultaneous) stimuli, are, together with absolute intensity (i), duration, and the other internal and external factors (t, s, c, a, n) major determinants of the extent and duration of electrolytic activity within the cerebral cortex. Hence they are the major determinants of the *form of closure* and of resultant engrams.

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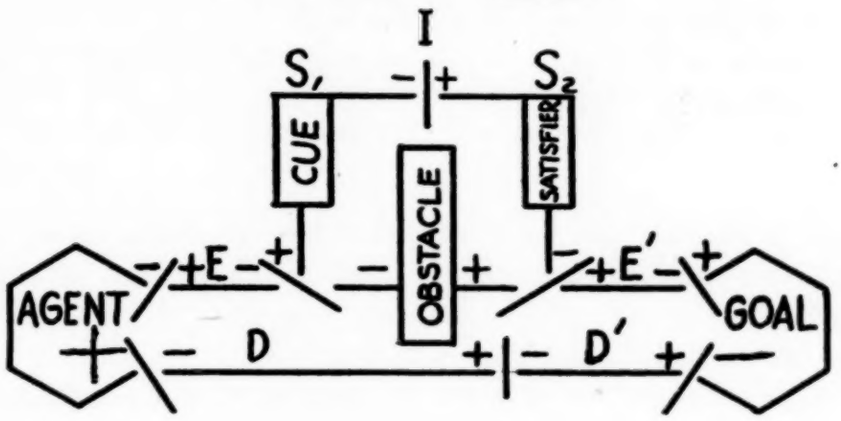
* Number and concentration of free charges is obviously related not only to intensity and duration of stimulation, but also to vividness of stimulation—*i.e.*, to its compactness and contrast with background.

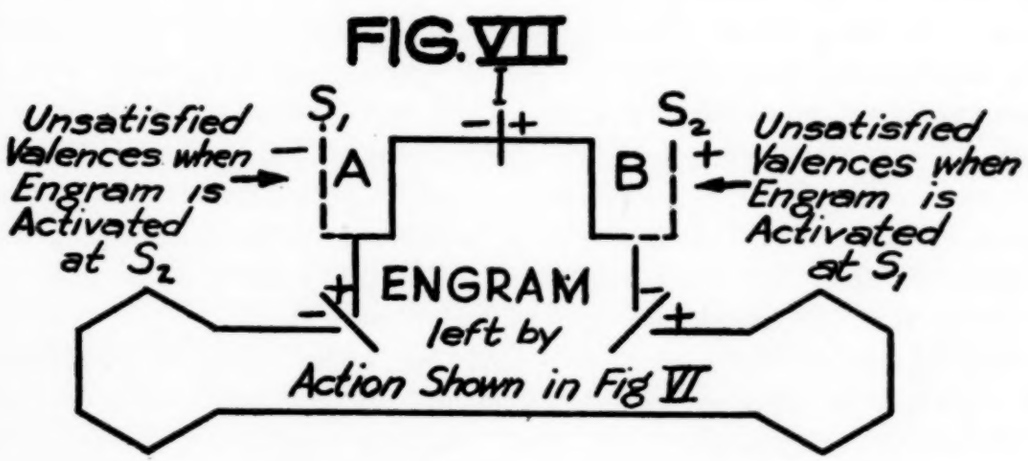
All of these factors, with different emphases, govern not only the initial formation but also the combination, substitution, and extinction of cerebral closures.

FIG. VI



The initial formation of a closure is depicted in Fig. VI. Here S_1 represents any stimulus pattern the reaction to which is relatively incomplete or open and which is *superseded* by reaction to S_2. *It*

FIG. VII



should be noted that the removal of a stimulus may be accomplished simply by the distraction of attention from it.

In Fig. VI the onset and removal of S_1 leaves surplus positive and negative charges which aid in bridging the gap (or surmounting the obstacle) between E and E'. These two pathways have opposite potentials because of the activity of the agent which, like an external stimulus, eminates waves of negativity (along E). And, as when an

external stimulus is removed, attracts negative charges (along *D*). This (which probably depends upon the intermittency of agent activity) results in a spread of surplus *positive* charges until, at *E'*, an obstacle is encountered. Thus the condition of the organism calls for an $S_1 - S_2$ sequence, in order to gain equilibrium. *The onset and removal of S_1 carries the surplus negative charges around the obstacle, the onset and removal of S_2 completes the circuit.*

The result is a closure. The engram left by such a closure is diagrammed in Fig. VII.

. . . . . .

When an engram has been formed it may be reactivated *as a unit*, providing the basic cerebral (agent-goal) potentials are propitious, by the reintroduction of either the cue stimulus, S_1, or the satisfier stimulus, S_2.

If it is reactivated by S_2 in the absence of S_1, cue substitution may occur. If substitute (or original) cues are sufficient, as in Fig. VI or VIII, to bridge the gap in an equilibrium system created by an obstacle, *behavior typical of immediate insight occurs.*

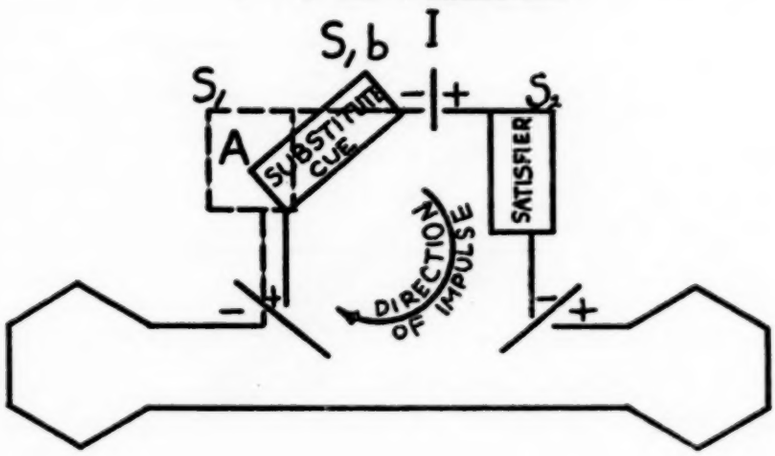
But if obstacles are increased, so that when one is avoided another is encountered, *cue substitution continues in a manner typical of trial and error.* In other words, the only important difference between immediate insight and trial and error is a difference in the adequacy of S_1 to carry activity around an obstacle. Thus to represent trial and error in Fig. VI, a further obstacle would have to be introduced at *I*; that is, activity arising from S_1 and S_2 would not be permitted to join at that point. Such a situation might arise because a particular satisfier was perceived, as in the case of Thorndike's hungry cats, or because its memory is revived in the absence of the satisfier itself.

In the case of Thorndike's cats (38) the "agent" may be considered as representing the motor organism of the cat whose viscera are rhythmically contracting; the "goal" may be considered as representing the disequilibrium caused by an empty stomach—the gap in the digestive pattern—or the failure of return sensations from the digestive tract (and of the general chemical condition of the body) to "take care of" the charges released by the activities of the agent. S_2 may be considered as representing the food; the "obstacle" (which in this case extends above the point *I* in Fig. VI) as representing the sight, pressure, etc. of the bars of the cage, and S_1 as any other *noticed* stimulus pattern.

In a case of this sort, where the experimentor holds S_2 constant, by displaying the food, and holds the agent-goal relationship constant by starving the cat, S_1 is bound to vary. For under these circumstances, the direction of the "current" (wave of negativity) is *through* the areas disturbed by S_1 *toward* the areas disturbed by S_2, and when an obstacle is encountered the result will be similar to that which occurs when any current meets an obstacle: If it cannot break through, it will shift and spread. When proprioceptive and exteroceptive patterns are shifted in this fashion, the process appears as trial and error behavior.

If an engram is activated by S_1 in the absence of S_2, the result is the anticipatory adjustment typical of a Conditioned Reflex.

FIG. VIII



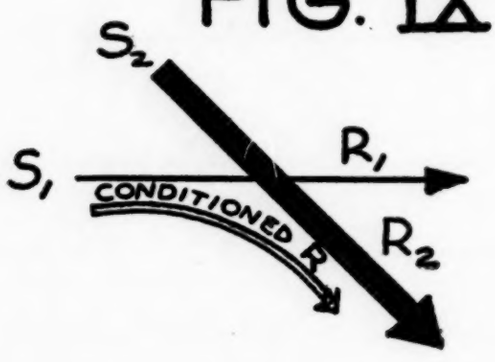
The conditioned reflex type of learning as well as trial and error, involves cue substitution. The chief difference between the two modes of substitution is simply that in trial and error the agent-goal base (and usually the satisfier perception or memory) are present at the time the cue stimulus first occurs; whereas in the type of substitution involved in the conditioned reflex, the reaction to the cue stimulus occurs first and the agent-goal-satisfier part of the engram follows. In other words, the channel of least resistance which may be created by the substitute S_1b shown in Fig. VIII is, in the case of the conditioned reflex, actually present (due to the sequence of events) when the rest of the engram is activated, and in the case of trial and error it is not.

In Fig. VIII the area marked "substitute" represents an open spread of free ions arising from S_1b, a stimulus of sufficient intensity to

attract attention—for example, the ringing of a bell. The charges thus released remain free for awhile because they are not at once engaged in an active closure system—the bell, in other words, does not seem to "belong" to, or to be intimately "tied up with," anything in the perceiver's surroundings or actions.

While this condition lasts *but after the onset and removal* of (or distraction of attention from) S_1b, the area marked "satisfier" is activated by S_2—for example, meat—and this results (the condition of the organism being propitious) in the activation of an agent-goal engram, such as, say, that shown in Fig. VII. The introduction of S_2, the meat, has satisfied the valences of area *B* (Fig. VII), but the valences at area *A*, created by the stimuli which customarily preceded ("heralded") the occurrence of meat, are left unsatisfied. However, the substitute stimulus, the bell, has left an accumulation of free

FIG. IX



ions which conveniently bridges the gap in the pattern. This bridge thereby becomes part of the closure, and the bell cue becomes tied into the engram.

Figure IX differs only in point of view from Fig. VIII. Both diagrams portray what happens in cue substitution: Fig. VIII indicates what may be deduced as happening in the cerebral cortex, Fig. IX shows what happens in the objectively observed behavior of the total organism.

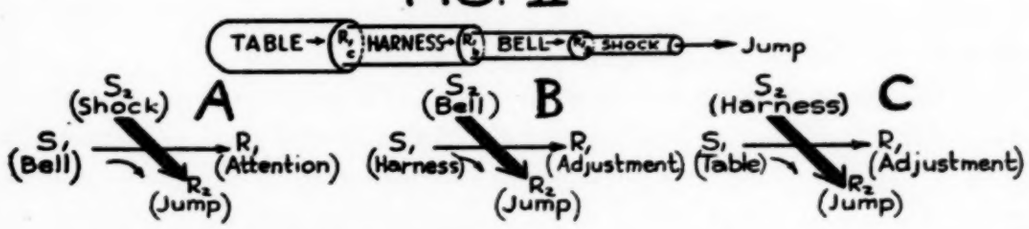
In Figs. VI to VIII S_1 and S_2, it will be recalled, designate simply two stimulus patterns which bear a certain time and intensity relationship to each other within a closure system. These relationships are represented in Fig. IX by the position of the two letters (S_2 following S_1) in the diagram, and by the size of the arrows going from them. The spread, intensity, and completeness of response which the stimuli

arouse is indicated by the breadth of the arrows R_1 and R_2. The overlapping of the less intense, widespread, and complete response (R_1) and the more intense, widespread, and complete response (R_2) is indicated by the crossing of the arrows. The resultant ability of S_1 to activate R_2 is indicated by the curved arrow marked "Conditioned *R*."

S_2 in Fig. IX often corresponds to S_2 in Figs. VI and VIII—that is, with the original satisfier. It always does so at the beginning of a learning series. But later on, in the phenomenon of "associative shifting" or "telescoping" we see that the cue (S_1 in Fig. IX) may act in place of the satisfier to activate the entire engram. When this happens the S_2 in Fig. IX corresponds to the S_1 of Figs. VI and VIII, and the S_1 in Fig. IX corresponds to the S_1b of Fig. VIII.

How this occurs is illustrated in Fig. X. Here we have taken as a case of typical telescoping (or associative shifting) the behavior of a

FIG. X



sheep which was brought into a laboratory, placed on a table, harnessed (in a manner similar to Pavlov's dogs (32)) exposed to the sound of a bell, and given a severe electric shock. As the sequence was repeated the sheep jumped first at the shock, then at the sound of the bell, than at being harnessed, and finally at being placed on the table.

This phenomenon may be described either as the "telescoping out" of the shock, bell, and harness stimuli, or it may be described as a series of conditioned reflexes as shown in Fig. X, *A*, *B*, *C*. As shown here, the bell stimulus precedes the shock and gives rise to an incomplete* (unclosed) response which affords a path of low resistance to the more complete response to S_2. The response to the bell is therefore included in the shock closure pattern as a substitute cue, capable, under favorable conditions, of activating that pattern. When the sequence is subsequently repeated, the harness stimulus precedes the

* Woodworth (45, p. 170) says in describing learning, "The dominant activity of any moment tends to absorb any other present activity that is hanging fire or undischarged, and thus to establish a connection from that other activity to the dominant activity; which connection is strengthened by repeated use."

bell which activates the more intense (than harness-response) shock-response pattern, the harness therefore becomes a substitute cue etc.

It can be seen that this explanation also accounts for the "backward action" of satisfaction (*i.e.* goal achievement or annoyer avoidance) which has given rise to considerable speculation.

. . . . . .

It appears then that associative shifting and telescoping are not unique forms of learning but merely a continuation of the process of conditioning. Indeed, from the viewpoint of the Closure Theory there are no unique forms of learning. Trial and error, the conditioned reflex, and immediate insight, all are but different modes of completing, activating, and coordinating cerebral closure systems.

All cerebral closures arise from and are altered by simultaneous and successive interoceptive, exteroceptive, and proprioceptive stimulation; and each of these three types of stimulation arises from the action of the organism upon its environment as well as from the action of the environment upon the organism.

No matter which of the three fields of stimulation is predominant, closure forms are subject to the action of agent and goal as depicted in Fig. VI. In any field the activity of the agent may build up areas of high and low potential which will determine the *general* nature of the satisfier, and in any field the environment may determine the specific nature of the satisfier, the obstacles, and the cues—in short the means of meeting a need.

So it appears that the Closure Theory has met the two major deficiencies of the synaptic hypothesis: It has accounted for the fact that the nature of a task (or goal) determines the nature of associative groupings; and it has accounted for the fact that retention of associative groupings depends upon belongingness as well as upon repetition. In addition to this it has accounted for many of the phenomena of perception, and has shown that all types of adjustive behavior are traceable to the same basic physical relationships.

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TEACHERS' REPORTS OF THE PROBLEMS OF UNADJUSTED SCHOOL CHILDREN

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What is the attitude of public school teachers toward the behavior problems of their pupils? Are they most concerned about violations of school regulations, or are they most concerned about the personality deviations that are likely to disturb the child's happiness and to retard his general development? Does the teacher think of a "problem child" as one "who is disorderly, restless, disobedient," or as one "who is unsocial, feels inferior, does not know how to play with other children"?

SUMMARY OF LITERATURE

Wickman[1] attempted to ascertain teachers' attitudes toward children's behavior in a study conducted in a Minneapolis public school in 1924 and in a Cleveland public school during 1925–1926. Twenty-nine Minneapolis teachers and twenty-seven Cleveland teachers listed types of problem behavior that they had observed in pupils. A list of fifty-one items thus obtained was submitted to the twenty-three "home-room" teachers in the Cleveland group, and the teachers were asked to rate each of their pupils with respect to each item, stating whether the behavior in question "has never occurred," "has occurred once or twice," "recurs with occasional frequency," or "has become almost habitual." Basing his judgment upon these ratings, Wickman concluded that the behavior problems which most interest teachers are those relating to school requirements—infractions of classroom rules and routine and failure to meet school work requirements. The personality problems of the children, according to Wickman, are subordinated to problems of classroom management.

The twenty-three Cleveland "home-room" teachers were also asked to state for each pupil whether he was "exceptionally well-adjusted," had "only minor behavior difficulties," had "behavior difficulties of some importance," or presented an "extremely serious

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[1] Wickman, E. K.: *Children's Behavior and Teachers' Attitudes.* New York, The Commonwealth fund, Division of Publications, 1928.

behavior problem." Sixteen "home-room" teachers listed a total of sixty pupils as "extremely serious behavior problems" (six cases) or as presenting "behavior difficulties of some importance" (fifty-four cases). Forty-six of the sixty pupils were boys and fourteen were girls—a ratio of approximately seven boys to two girls. Wickman studied the ratings previously given by the teachers to these sixty pupils, on the fifty-one items of behavior. On the basis of the ratings given by the sixteen teachers, he concluded that the problem child, to the teacher, is one who is antagonistic to authority, disturbs classroom routine, does not apply himself to prescribed school work, and violates the teacher's standards of integrity; and that personality problems which do not interfere with the immediate purposes of the teacher are not recognized as signs of maladjustment.

Ratings on the relative seriousness of fifty types of problem behavior were secured from the Cleveland teachers and from "control groups" (totaling five hundred ninety-two teachers) in other communities. The items were rated as "of no consequence," "of only slight consequence," "makes for considerable difficulty," or "an extremely grave problem." Wickman concluded that behavior which offends the teachers' moral standards and challenges their authority or which interferes with classroom routine is regarded as relatively more serious than personality problems which affect the general welfare of the child, and that aggressive behavior is considered more serious than regressive behavior.

The teachers' ratings of the relative seriousness of the various behavior problems were at variance with the ratings given these problems by a group of thirty clinical workers (psychiatrists, psychologists, psychiatric social workers, and visiting teachers). The clinicians ranked undesirable personality traits as most serious, gave a median ranking to violations of moral standards, and regarded violations of school regulations as least serious. The clinicians considered, in most cases, recessive traits more serious than aggressive traits.

Wickman's study was repeated in part by Laycock,[1] working under a grant given in 1929 by the Canadian National Committee on Mental Hygiene. Laycock had the one hundred sixty-seven elementary school teachers in the city of Saskatoon, Saskatchewan, Canada, to list the behavior problems they had observed in pupils, and to rate the one

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[1] Laycock, S. R.: "Teachers' Reactions to Maladjustments of School Children." *British Journal of Educational Psychology*, Vol. IV, Part 1, 1934, pp. 11–29.

hundred nine items thus obtained as to frequency of occurrence and as to seriousness. No ratings of individual pupils were obtained. Laycock reported his results to be in harmony with those of Wickman; violations of school work regulations, of classroom rules, and of general school regulations were considered "outstandingly more frequent" than undesirable personality traits, transgressions against authority or violations of standards of morality. Moreover, violations of standards of morality, transgressions against authority, violation of school and classroom regulations and of school work requirements were considered more serious than pupils' difficulties with other children or undesirable personality traits. The Canadian teachers differed from Wickman's group only in rating regressive personality traits as more serious than aggressive traits. In general, Laycock's results may be said to support Wickman's conclusion that teachers are most concerned about behavior that interferes with their immediate purposes and feel relatively little concern about the personality problems of the child.

Neither Wickman nor Laycock asked the teachers contributing to his study the direct questions, "What children in your classrooms do you consider most poorly adjusted? Why do you judge them to be maladjusted?" Both investigators sought answers to these questions only by inference. Laycock dealt with abstract items of behavior and secured no pupil-ratings. Wickman, while securing from sixteen teachers the names of children believed to be poorly adjusted, did not ask the teachers directly to state the problems which caused them to consider the children maladjusted.

PROCEDURE

During the summers of 1932, 1933, and 1934, the writer announced to teachers enrolled in her classes in child psychology (a non-advanced course) in the University of Texas that each might hand in a case study of an unadjusted pupil. The writing of a case study was not obligatory; if the student desired a short reading could be substituted. However, only one teacher chose not to write the case study. The teachers contributing the case studies were employed in Texas public schools, some in the largest cities of the State, others in small towns and in rural districts. Both elementary and high school teachers were represented. The directions given the students for writing the case study were brief: "Tell why you consider the pupil maladjusted,

explain as well as you can the factors tending to cause the maladjustment, and state what you think should be done for the child." The case studies were written after the students had been in the class from two to three weeks; they were called for prior to the class discussion of mental hygiene, delinquency, and adolescent adjustment.

While, for the most part, the teachers studied by Wickman and Laycock rated abstract items of behavior, the teachers studied in the present investigation reported their reactions to the specific problems of actual children. Reports obtained by this second method might be expected to represent more truly the real attitude of the teachers toward the behavior of their pupils.

RESULTS

Case studies of one hundred seventy-five maladjusted children were secured by the method just described. One hundred and fourteen were of boys (fifty-two of adolescents and sixty-two of preadolescents, if the age of fourteen may be considered the average[1] for the beginning of puberty in boys); and sixty-one were of girls (twenty-six of adolescent and thirty-five of preadolescents, if the age of thirteen may be considered the average for the beginning of puberty in girls). The sexes were thus represented in the ratio of about two boys to one girl. A total incidence of six hundred ninety-eight problems of ninety different types was reported for the one hundred seventy-five children, an average of four problems per child. For the one hundred fourteen boys, four hundred seventy-two problems were reported, an average of 4.14 problems per boy; for the sixty-one girls, two hundred twenty-six problems were reported, an average of 3.7 per girl.

The ninety types of problems discussed by the teachers may be classified in the seven groups listed by Wickman: (1) Violations of general standards of morality and integrity, (2) transgressions against authority, (3) violations of general school regulations, (4) violations of classroom rules, (5) violations of school work requirements, (6) difficulties with other children, and (7) undesirable personality traits. Undesirable personality traits were subdivided by Wickman into two groups, the aggressive and regressive. These two subdivisions have been observed in the present study, and a third, "a-typical mental traits," has been added. Under this last heading have been grouped a

[1] In a few reports, retarded or accelerated pubescence was definitely indicated, and the children were classified accordingly.

number of problems, not suggested by the teachers contributing to Wickman's study, but reported by the teachers assisting in the present investigation.

Table I indicates the incidence of the different kinds of behavior problems, judged by the percentage of the total six hundred ninety-eight problems accounted for under the various classifications. Undesirable personality traits are reported most frequently, accounting for fifty-three per cent of all the problems listed. Regressive traits are more frequently reported than aggressive traits, the respective percentages being thirty-one and nine, with a-typical mental traits accounting for thirteen per cent of all the problems named. Next

TABLE I.—INCIDENCE OF DIFFERENT KINDS OF BEHAVIOR PROBLEMS

Kind of behavior	Percentage of all (six hundred ninety-eight) problems reported		
	Entire group	Boys	Girls
1. Undesirable personality traits	53	51	59
Aggressive traits	09	09	09
Regressive traits	31	28	39
A-typical mental traits	13	14	11
2. Violations of general standards of morality and integrity	16	16	16
3. Violations of school work requirements	16	18	11
4. Violations of classroom rules	07	08	05
5. Difficulties with other children	04	03	05
6. Violations of general school regulations	03	03	03
7. Transgressions against authority	01	01	01
Total	100	100	100

most common are violations of general standards of morality and integrity, sixteen per cent, and violations of school work requirements, also sixteen per cent. Violations of classroom rules account for seven per cent of the total number of problems; difficulties with other children, four per cent; violations of general school regulations, three per cent; and transgressions against authority, one per cent.

Apparent sex differences are greatest in regressive personality traits (representing thirty-nine per cent of all problems for girls, twenty-eight per cent for boys) and in violations of school work require-

TABLE II.—VIOLATIONS OF GENERAL STANDARDS OF MORALITY AND INTEGRITY

Problem	Incidence among one hundred seventy-five unadjusted children				
	Entire group	Preadolescent boys (sixty-two)	Adolescent boys (fifty-two)	Preadolescent girls (thirty-five)	Adolescent girls (twenty-six)
1. Stealing	28	10	12	4	2
2. Lying	22	5	6	6	5
3. Heterosexual activity	11	..	5	3	3
4. Swearing	8	3	4	1	..
5. Drinking	7	..	7	..	..
6. Obscene language, pictures, notes	5	..	1	4	..
7. Teaching sex behavior	5	2	2	..	1
8. Undue interest in opposite sex	4	2	..	..	2
9. Exhibitionism of genitals	3	1	1	1	..
10. Homosexual activity	3	..	3		..
11. Masturbation	3	1	1	1	..
12. Bootlegging	2	..	2	..	..
13. Cheating	2	..	..	..	2
14. Excessive smoking	2	..	2	..	..
15. Gambling	2	..	2	..	..
16. Sex phantasy	2	..	1	..	1
17. Begging	1	1			
Total	110	25	49	20	16

ments (eighteen per cent of all problems for boys and eleven per cent for girls). These differences are not reliable, none being three times the standard deviation of the difference.*

* $\sigma = \sqrt{\frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2}}$ when p_1 and p_2 represent the respective percentages, q_1 and q_2 the respective differences obtained by subtracting the two percentages from one hundred per cent, and n_1 and n_2 the respective number of cases. The criterion for a significant difference used in this study is that the difference equal at least 3σ.

Tables II to VIII inclusive show in detail the incidence of the ninety problems reported, grouped under the seven classifications suggested by

TABLE III.—TRANSGRESSIONS AGAINST AUTHORITY

Problem	Incidence among one hundred seventy-five unadjusted children				
	Entire group	Preadolescent boys (sixty-two)	Adolescent boys (fifty-two)	Preadolescent girls (thirty-five)	Adolescent girls (twenty-six)
1. Disobedience	5	..	2	2	1
2. Disrespectfulness	3	..	2	..	1
Total	8	..	4	2	2

Wickman, and listed separately for boys and for girls, for adolescents and for preadolescents. A slightly greater average number of prob-

TABLE IV.—VIOLATIONS OF GENERAL SCHOOL REGULATIONS

Problem	Incidence among one hundred seventy-five unadjusted children				
	Entire group	Preadolescent boys (sixty-two)	Adolescent boys (fifty-two)	Preadolescent girls (thirty-five)	Adolescent girls (twenty-six)
1. Truancy	14	2	8	1	3
2. Truancy that includes running away from home	4	1	2	1	..
3. Irregular attendance	3	2	..	..	1
Total	21	5	10	2	4

lems is reported for adolescents than for preadolescents of both sexes. For the sixty-two preadolescent boys, a total of two hundred thirty-

TABLE V.—VIOLATIONS OF CLASSROOM RULES

Problem	Incidence among one hundred seventy-five unadjusted children				
	Entire group	Preadolescent boys (sixty-two)	Adolescent boys (fifty-two)	Preadolescent girls (thirty-five)	Adolescent girls (twenty-six)
1. Disorderliness	15	6	5	4	..
2. Restlessness	15	8	3	3	1
3. Disturbing other children in class	10	8	2	..	..
4. Destructiveness	4	2	..	2	..
5. Attracting attention	3	1	1	..	1
Total	47	25	11	9	2

TABLE VI.—VIOLATIONS OF SCHOOL WORK REQUIREMENTS

Problem	Incidence among one hundred seventy-five unadjusted children				
	Entire group	Preadolescent boys (sixty-two)	Adolescent boys (fifty-two)	Preadolescent girls (thirty-five)	Adolescent girls (twenty-six)
1. Poor school marks	69	26	27	7	9
2. Lack of interest in studies	23	6	12	2	3
3. Inattention	8	6	2	..	..
4. Lack of effort	7	1	4	..	2
5. Dislike for school	3	3	..	..	..
Total	110	42	45	9	14

TABLE VII.—DIFFICULTIES WITH OTHER CHILDREN

Problem	Incidence among one hundred seventy-five unadjusted children				
	Entire group	Preadolescent boys (sixty-two)	Adolescent boys (fifty-two)	Preadolescent girls (thirty-five)	Adolescent girls (twenty-six)
1. Bullying	9	2	5	..	2
2. Fighting	6	1	2	2	1
3. Quarrelling	5	1	2	2	..
4. Roughness	3	1	..	2	..
5. Epileptic attacks on other children	3	2	..	1	..
6. Leading other children into mischief	1	..	..	1	..
7. Tattling	1	..	..	1	..
Total	28	7	9	9	3

TABLE VIII.—UNDESIRABLE PERSONALITY TRAITS

A. Aggressive Traits

Problem	Incidence among one hundred seventy-five unadjusted children				
	Entire group	Preadolescent boys (sixty-two)	Adolescent boys (fifty-two)	Preadolescent girls (thirty-five)	Adolescent girls (twenty-six)
1. Domineeringness	15	3	6	5	1
2. Quick temper	15	3	6	4	2
3. Resentfulness	9	2	5	2	
4. Rudeness	9	2	4	1	2
5. Egotism	6	..	2	1	3
6. Stubbornness	6	..	5	..	1
7. Sulkiness	4	..	4	..	..
Total	64	10	32	13	9

TABLE VIII.—*Continued*
B. Regressive Traits

Problem	Incidence among one hundred seventy-five unadjusted children				
	Entire group	Preadolescent boys (sixty-two)	Adolescent boys (fifty-two)	Preadolescent girls (thirty-five)	Adolescent girls (twenty-six)
1. Nervousness	30	10	5	11	4
2. Feeling of inferiority	23	7	4	4	8
3. Does not know how to make social contacts	20	8	4	4	4
4. Unsocialness, seclusiveness	20	9	1	6	4
5. Unpopularity	14	1	4	6	3
6. Unhappiness	12	4	4	2	2
7. Sensitiveness	10	3	4	1	2
8. Shyness	9	5	2	..	2
9. Cries easily	8	2	1	4	1
10. Emotional instability	8	2	4	2	
11. Laziness	8	..	7	..	1
12. Dreaminess	6	3	2	..	1
13. Fearfulness	6	1	..	4	1
14. Believes self discriminated against	4	1	2	..	1
15. Feeling of being unwanted, unloved	4	1	3	..	..
16. Over-dependence on mother	4	..	1	2	1
17. Worry	4	1	2	..	1
18. Involuntary nervous movements	3	2	1	..	..
19. Loafs on street	3	1	2	..	..
20. Not interested in anything	3	..	2	..	1
21. Feelings of guilt	2	1	..	1	..
22. Hysterical illness	2	1	..	1	..
23. Lack of persistence	2	..	2	..	..
24. Over-critical of others	2	..	2	..	..
25. Suspiciousness	2	..	1	1	..
26. Suicide	2	..	2	..	..
27. Too quiet, too good	2	2	..	..	..
28. Untidiness	2	..	..	..	2
29. Lack of concentration	1	..	1	..	..
30. Easily discouraged	1	1	..	..	..
31. Easily led	1	1	..	..	..
32. Hysterical pains	1	..	..	1	..
33. Over-modesty	1	..	..	..	1
34. Rationalizes, makes excuses for self	1	1	..	..	..
Total	221	68	63	50	40

TABLE VIII.—*Continued*
C. A-typical Mental Traits

Problem	Incidence among one hundred seventy-five unadjusted children				
	Entire group	Preadolescent boys (sixty-two)	Adolescent boys (fifty-two)	Preadolescent girls (thirty-five)	Adolescent girls (twenty-six)
1. Seeming dullness or mental deficiency	41	..	..	..	..
(*a*) Evidenced by intelligence test	..	6	1	..	1
(*b*) Evidenced only by teacher's observation	..	16	9	4	4
2. Speech difficulties (including stammering)	15	11	1	..	3
3. Specialized inability in one school subject	14	9	..	3	2
4. Ability seemingly too high for adjustment to ordinary school program	5	5	..	..	..
5. Epilepsy	4	2	1	1	..
6. After-affects of poliomyelitis	3				
(*a*) Character change	..	..	2	..	..
(*b*) "Forgetting" of school subjects	..	..	..	..	1
7. Birth injury to brain	2	1	..	1	..
8. Mirror writing	2	1	..	1	..
9. Neurosis (diagnosed by physician)	2	1	..	..	1
10. Conduction aphasia	1	1	..	..	..
Total	89	53	14	10	12

five problems is reported, an average of 3.79; for the fifty-two adolescent boys, a total of two hundred thirty-seven problems, an average of 4.55; for the thirty-five preadolescent girls, a total of one hundred twenty-four problems, an average of 3.54; for the twenty-six adolescent girls, a total of one hundred two problems, an average of 3.92. As already pointed out, a greater number of problems is reported for the boys as a whole than for the girls.

More violations of general standards of morality and integrity are found among adolescent than among preadolescent boys. Preadolescent boys and girls show more violations of classroom rules, but adolescent boys and girls show more violations of general school regulations. Adolescents are reported as violating school work requirements more often than preadolescents. Difficulties with other children are more frequent among girls in preadolescence, but among boys in adolescence. Undesirable aggressive traits become more frequent among boys in adolescence. A-typical mental traits are less common among adolescent boys than among any of the other groups; perhaps there is a tendency for the a-typical adolescent boy to be eliminated from school.

The term "disciplinary offenses" may be used to include transgressions against authority, difficulties with other children, violations of classroom rules, and violations of general school regulations. Such disciplinary offenses, violations of general standards of morality and integrity, and aggressive personality traits are not reported at all by ninety-four, or fifty-four per cent, of the one hundred seventy-five teachers. Eighty-one, or forty-six per cent of the teachers, do report such types of behavior. The reactions of these teachers to the pupils' aggressive and anti-social behavior are of three types, as indicated in Table IX.

First, nine teachers (five per cent of the one hundred seventy-five) describe the undesirable behavior as a complete problem within itself, not relating it to other phases of the child's development. These teachers fail to perceive the child's activities as a pattern or whole, and they seemingly lack the insight necessary to explain the problem behavior in relation to the child's total development. *Examples:*

(1) "The problem in R. L.'s case is a disciplinary one. He has a very bad disposition."

(2) "H. certainly misbehaves. He gets his assignments more quickly than the other children, and then becomes idle and starts misbehaving. His mother says that he has always been bad."

Second, forty-four teachers (twenty-five per cent of the one hundred seventy-five) explain undesirable aggressive and anti-social behavior in terms of environmental influences. *Examples:*

(1) "Buddy has 'sticky fingers.' His parents punish their children for getting caught, not for stealing."

(2) "M.'s trouble (stealing small articles) lies chiefly in habit, I think. Then, too, poverty has been a contributing factor. His weakness is likely to lead to worse misdemeanors if uncorrected."

Third, twenty-eight teachers (sixteen per cent of the one hundred seventy-five) explain undesirable aggressive traits and anti-social behavior as a form of compensation for regressive tendencies. *Examples:*

(1) "He has a sort of inferiority complex that he tries to hide by clowning and bragging."

(2) "We cannot blame this girl for her present condition, but must adjust the school to remold her outlook on life."

(3) "J. lacked the feeling of security; she was given very little attention and practically no recognition."

TABLE IX.—TEACHERS' REACTIONS TO AGGRESSIVE AND ANTI-SOCIAL BEHAVIOR

Teachers' report	Number of teachers	Percentage of one hundred seventy-five teachers
1. No undesirable aggressive traits, disciplinary offenses, or violations of moral standards reported	94	54
2. Such behavior reported, but not explained in relation to the child's total development	9	05
3. Such behavior reported, and explained in terms of environmental influences	44	25
4. Such behavior reported, and explained as a form of compensation for regressive traits	28	16
Total	175	100

(4) "He disturbs everyone—probably due to such extreme inhibition at home."

(5) "C.'s boastful, 'I'm a tough guy,' air is, I think, simply a form of over-compensation. He is extremely sensitive. This tough shell he has adopted is to prevent anyone from seeing him as he really is, without love, kindly attention, or worldly goods."

(6) "He needs something on which to build some happiness for himself."

(7) "He was never a happy child, and he always had the feeling that he was oppressed."

(8) "Her relation with the boy was the result of her desire to secure the attention of the other children. She felt left-out, and she thought

that would make her outstanding. It was not, I think, the result of a sex urge."

SUMMARY AND CONCLUSIONS

Each of the one hundred seventy-five teachers contributing to the present investigation wrote a case study of a maladjusted pupil and stated the problems which caused him or her to consider the pupil maladjusted. A total of six hundred ninety-eight problems was reported for the one hundred seventy-five pupils. Fifty-three per cent of these problems may be classified as undesirable personality traits: regressive traits, thirty-one per cent of the total; aggressive traits, nine per cent; and a-typical mental traits, thirteen per cent. Undesirable personality traits are thus reported as the chief reason for considering pupils maladjusted. A position of median importance is assigned to violations of school work requirements and to violations of conventional standards of morality and integrity, sixteen per cent of the problems reported falling into each of these classifications. A total of fifteen per cent of the problems may be classified as disciplinary offenses: violations of classroom rules, seven per cent; difficulties with other children, four per cent; violations of general school regulations, three per cent; and transgressions against authority, one per cent. Little emphasis is placed upon any one of these types of disciplinary offenses.

More boys than girls were reported as maladjusted, in the ratio of two to one. However, evidently fewer problems were necessary to cause a girl to be regarded as maladjusted, for a smaller average number of problems was reported for girls than for boys. Moreover, fewer problems were reported for the preadolescents than for the adolescents. Preadolescent girls averaged 3.54 problems each; adolescent girls, 3.92; preadolescent boys, 3.79; and adolescent boys, 4.55. The average for all the boys was 4.14 problems; for the girls, 3.7; for both sexes, 4.

Apparent, but statistically unreliable, sex differences were reported, in that regressive traits were listed more frequently for girls (girls, thirty-nine per cent of all problems; boys, twenty-eight per cent), and that violations of school work requirements were listed more frequently for boys (boys, eighteen per cent; girls, eleven per cent).

Slight differences between adolescents and preadolescents were also noted; more violations of moral standards were found among adolescent than among preadolescent boys; preadolescent boys and girls violated more classroom rules than adolescents, but adolescents violated more general school regulations; more adolescents than preadolescents violated school work regulations; difficulties with other children were more frequent among girls in preadolescence, but among boys in adolescence; aggressive traits were more frequently noted for adolescent than for preadolescent boys; a-typical mental traits were reported less frequently for adolescent boys than for any other group, perhaps because there is a tendency for a-typical adolescent boys to be eliminated from school.

Fifty-four per cent of the teachers contributing to the present study reported no aggressive traits, violations of moral standards, or disciplinary offenses. The forty-six per cent reporting such problems showed three distinct types of reaction: five per cent saw the aggressive or anti-social behavior as a problem in itself, unrelated to the total development of the child; twenty-five per cent explained such behavior in terms of environmental influences; and sixteen per cent explained such behavior as a form of compensation for regressive personality traits.

The teachers contributing to the present investigation put upon behavior problems almost the opposite emphasis to that reported by Wickman and by Laycock. While these investigators reported their teachers as considering undesirable personality traits least serious and disturbances of school routine most serious, the teachers concerned in the present study gave overwhelming emphasis to undesirable personality traits, considered the various classes of disciplinary offenses as least serious, and placed a median emphasis upon violations of moral standards and of school work requirements. The opinions of the teachers studied in the present investigation resembled those of Wickman's clinicians rather than those of Wickman's or of Laycock's teachers. They agreed with the Canadian rather than the Cleveland group in regarding aggressive traits as of less consequence than regressive traits.

The technique used in securing the teachers' responses has probably influenced the results of each study. The teachers studied by Wickman and by Laycock rated abstract items of behavior. Only the sixteen teachers in Wickman's Cleveland "homeroom" group were asked to consider the adjustment of actual children, and even these

teachers were not asked to state which problems caused them to list a given child as maladjusted. The teachers studied in the present investigation reported their reactions to the specific problems of actual children. Reports thus obtained probably have greater validity as representing the real attitude of the teachers toward the behavior of their pupils.

THE MOST PREDICTABLE CRITERION

HAROLD HOTELLING

Columbia University

Several measurable criteria may often be found which can be taken as estimates of a single non-measurable and often ill-defined variable, such as college success, or the general price level. When it is desired to predict the non-measurable variable by means of a second set of observable quantities, such as the examination and test grades recorded for applicants for college admission, no single regression equation can provide a fully adequate solution. Any combination of criteria may be used as the dependent variate in a regression equation. The principle basic to the combination will vary from case to case, according to circumstances; and in general not one but several regression equations must be used to give a proper picture. In some circumstances, particularly when the criterion variates are numerous, it may be well to use as the dependent variate in a regression equation that linear function of the criteria whose mean square correlation with them is a maximum. This function is the first of what I have elsewhere called the principal components of the set.[1] Sometimes two or more of the principal components may well be used as dependent variates. In other cases extraneous considerations will be the dominating ones in the choice of a quantity to be predicted; for example, college grades in some subjects may be deemed more suitable measures of success in what the college is trying to do than grades in other subjects, for reasons not determined by statistical calculations. In spite of this variety of grounds for choice of a variate to be predicted, the problem of finding a linear function of the criterion variates which can *most accurately* be predicted from given observations, in the sense of least squares, admits a definite solution, which we shall set forth.

If there are p variates which may be called "predicters," such as scores in college entrance examinations of various kinds, and q others which will be called the criteria, such as college grades, of which some function to be chosen is to be predicted, let us denote these variates by x_i and x_α respectively, with the understanding that Greek indices take all values from 1 to p, while Latin indices take values from $p + 1$ to $p + q$, inclusive. Thus Greek subscripts, and also the Greek super-

[1] "Analysis of a Complex of Statistical Variables into Principle Components." *Journal of Educational Psychology*, Vol. XXIV, September and October, 1933, pp. 417–441 and 498–520. Published separately as a pamphlet by Warwick and York, Baltimore.

scripts which will be used, refer to the criterion variates, while Latin subscripts and superscripts refer to the predicters. We shall, further, make use of the convention that the double occurrence of an index in a term, once as subscript and again as superscript, means that the term is to be summed with respect to this index. The summation will be over all the criterion variates if the index is Greek, but over the predicters if the index is Latin. An arbitrary linear function of the criteria may thus be written

$$z = a^{\alpha}x_{\alpha}.$$

Our problem is to choose the constants a^{α} in such a way that z will have the greatest possible multiple correlation with the predicters x_i; this is equivalent to the requirement that z be estimated from a regression equation with the smallest possible mean square error, provided the variance of z is held to a fixed value, for example unity.

If r_i denote the correlation of z with x_i, while r_{ij} is the correlation of x_i and x_j, the multiple correlation may be written

$$R^2 = r^{ij}r_ir_j, \tag{1}$$

where r^{ij} is the cofactor of r_{ij} in the determinant of the correlations among the predicters, divided by the determinant. This formula for the multiple correlation is not well known, but is an immediate consequence of the usual expression in terms of a ratio of determinants, obtainable by expanding the numerator determinant with respect to the row and column of correlations with the criterion z.

Taking the variance of each x_{α} as unity, that of z will be unity if

$$r_{\alpha\beta}a^{\alpha}a^{\beta} = 1, \tag{2}$$

where $r_{\alpha\beta}$ is the correlation of x_{α} and x_{β}, and a double sum over the predicters is indicated by the repetition of α and β. We then have for the correlation of z with x_i

$$r_i = r_{i\alpha}a^{\alpha}.$$

Substituting this in (1) we have

$$R^2 = r^{ij}r_{i\alpha}r_{j\beta}a^{\alpha}a^{\beta}, \tag{3}$$

which is to be made a maximum by choosing a set of a^{α} satisfying (2). The minimizing conditions are

$$(r^{ij}r_{i\alpha}r_{j\beta} - \lambda r_{\alpha\beta})a^{\alpha} = 0 \tag{4}$$

where λ is a Lagrange multiplier. Putting for brevity

$$w_{\alpha\beta} = r^{ij}r_{i\alpha}r_{j\beta},$$

these may be written

$$(w_{\alpha\beta}-\lambda r_{\alpha\beta})a^{\alpha} = 0. \tag{5}$$

This set of p homogeneous linear equations in the p unknowns a^1, a^2, . . . , a^p will have a non-trivial solution only if the determinant is zero; that is, if λ is a root of the determinantal equation

$$|w_{\alpha\beta} - \lambda r_{\alpha\beta}| = 0. \tag{6}$$

If any root of this equation is substituted in (5), values of the a^{α} may be determined satisfying the linear equations, and then multiplied by a constant factor so as to satisfy (2). We shall also have, upon multiplying (4) by a^{β}, summing with respect to β, and then reducing with the help of (2) and (3),

$$R^2 = \lambda.$$

The last equation shows that, among all the roots of (6), the one to be used is the *largest*, since the root will actually equal the squared multiple correlation which we are trying to maximize. The other roots correspond to minimum or minimax values of R^2.

For $p = q = 2$, so that x_1 and x_2 are the criteria and x_3 and x_4 the predicters, (6) reduces to

$$(1 - r_{12}^2)(1 - r_{34}^2)\lambda^2 - (W_{11} - 2r_{12}W_{12} + W_{22})\lambda + (r_{13}r_{24} - r_{14}r_{23})^2 = 0,$$

where

$$W_{\alpha\beta} = (1 - r_{12}^2)w_{\alpha\beta}.$$

The greater root of this equation is to be substituted in

$$(w_{11} - \lambda)a + (w_{12} - \lambda r_{12})b = 0. \tag{7}$$

We have also in this case

$$w_{11} = 1 - \frac{\Delta_{22}}{1 - r_{34}^2} = (R_{.134})^2,$$

$$w_{22} = 1 - \frac{\Delta_{11}}{1 - r_{34}^2} = (R_{2.34})^2,$$

$$w_{12} = r_{12} + \frac{\Delta_{12}}{1 - r_{34}^2}$$

where $\Delta_{\alpha\beta}$ is the cofactor of $r_{\alpha\beta}$ in the four-rowed determinant of correlations. The quantities a and b determined by (7), identical with those previously denoted by a^1 and a^2, are the weights in the expression $ax_1 + bx_2$ for the most predictable function.

With a larger number of variates the calculations directly from the preceding formulae may become somewhat heavy. But if, as a

preliminary, an analysis into principal components, or any other uncorrelated components, has been performed upon the criteria, the remaining work may easily be accomplished by an iterative process similar to that used in the paper referred to for the determination of the first principal component. For if the x^α are such components, they are uncorrelated with one another, and (5) reduces to

$$w_{\alpha\beta}a^\alpha = \lambda a^\beta. \quad (\beta = 1, 2, \cdots, p)$$

Substitution of arbitrary quantities for the a^α in the left members of these equations yields new quantities whose ratios are improved estimates of those among the a^α, as shown in the previous paper. Upon substituting the new quantities, and continuing to repeat the process, the correct ratios are approached, as before, and in such a way that the ratio of two consecutive estimates of the same a approaches the greatest root λ.

It is entirely possible that the most predictable criterion thus defined will have little correlation with many of the original criteria, especially if they are numerous. But if, instead of using all the original criteria, or all their principal components, we use in the above process only the first few principal components, the mean square correlation with them, or with the original criteria of the function chosen for prediction will be increased.

In a space of dimensionality equal to the number of individuals measured, each variate may be represented by a point, or by a vector from the origin. The cosine of the angle between two such vectors is the correlation of the variates. p criterion variates thus determine p vectors from the origin, which of course must lie in a flat subspace of p dimensions. The q predicters lie in a flat sub-space of q dimensions. These two sub-spaces will in the most general case have no point in common other than the origin. The problem of the most predictable criterion is that of finding a line in the p-space making the least possible angle with the q-space. This minimum angle is also the least angle that a line in the q-space can make with the p-space. The geometry makes it evident that, if we interchange the roles of predicters and criteria, the maximum attainable value of R^2 remains the same. It also shows that the most predictable linear function of the criteria is identical with the regression function that most accurately predicts that function of the predicters which is most predictable in terms of the criteria; for these two functions are represented by the lines in the two flat spaces which are the sides of the minimum angle.

A STUDY OF THE DRAWINGS OF ABNORMAL CHILDREN

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In 1908 Sully said,[1] "I think that the first crude drawings are valuable as throwing light on the workings of children's minds. Perhaps indeed it may turn out that these spontaneous efforts of the childish mind to figure objects are, for the psychologist, a medium of expression of the whole of child nature, hardly less instructive than that of early speech."

More recently Goodenough by means of carefully defined characteristics has devised a method of objectively rating the drawings of children. The technic has proven of great value and the results give a reliable index of certain aspects of mental development as indicated by the published data.[2]

DeFursac,[3] Kurbitz,[4] Reja,[5] and Rouma[6] have all given evidence that mental deterioration or abnormalities of functioning may be revealed in drawings. This indeed does not seem to be at all unusual, as Goodenough has pointed out when she says:[7] "It is not entirely unreasonable that a form of expression so closely related to the child's mental life as is spontaneous drawings may perhaps reveal traces of such maladjustments."

The purpose of this study was to evaluate statistically certain tentative generalizations made by Goodenough concerning the drawings of psychopathic children and also to discover diagnostic differences on an item-by-item analysis of the data.

The children whose drawings are reported herewith were all committed to the Allentown (Pa.) State Hospital and ranged in age

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[1] Sully, James: *Studies in Childhood.* D. Appleton & Co., 1908, p. 332.

[2] Goodenough, F. L.: *The Measurement of Intelligence by Drawings.* World Book Co., 1926, p. 48.

[3] DeFursac, Rogues: *Les Ecrite et les Dessines dans les Maladies Nerveures et Mentales.*

[4] Kurbitz, W.: "Die Zeichnungen geistiskranker personen." *Zeitschrift fur die gesammte Neurologie und Psychiatry,* Vol. XIII, 1912, pp. 153–182.

[5] Reja, Marcel: "L'arte Malade: Dessim de Fous." *Revue Universelle.* Vol. I, 1901, pp. 913–915 and 940–944.

[6] Rouma, Georges: "Un Cas de Mythomanic." *Archives de Psychologic,* Vol. VII, 1908, pp. 258–282.

[7] Goodenough, F. L.: *Op. cit.*, p. 62.

from six years, nine months to seventeen years, five months. The group was divided into three sub-groups on the basis of diagnosis. The mean life age and the standard deviation are given for each sub-group in Table I.

TABLE I.—MEAN LIFE AGE AND GOODENOUGH SCALE RATINGS IN TERMS OF YEARS AND MONTHS

	Post-encephalitis	Psychopathic personality	Borderline deficiency
Mean life age	14–3	12–3	13–7
SD of life age	1–11	2–9	2–0
Goodenough scale rating	8–0	9–6	10–0
SD of Goodenough rating	2–5	2–2	1–8
N	24	13	15

As will be noticed there was a difference of two years in the means. Likewise the SD for the post-encephalitis group approximated that for the borderline deficiency group, while the psychopathic group had a SD

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* Key:

1. Head present.
2. Legs present.
3. Arms present.
4*a*. Trunk present.
4*b*. Length of trunk greater than width.
4*c*. Shoulders present. Concavity not convexity.
5*a*. Any attachment of limbs.
5*b*. Attachment of limbs at right point.
6*a*. Neck present.
6*b*. Neck outline continuous with head or trunk.
7*a*. Eyes present.
7*b*. Nose present.
7*c*. Mouth present.
7*d*. Features in two dimensions. Two lips shown.
8*a*. Hair present.
8*b*. Hair detail. Not transparent.
9*a*. Clothing present.
9*b*. Two articles non-transparent.
9*c*. Entirely non-transparent. Sleeves.
9*d*. Four articles shown.
9*e*. Complete costume. Soldier, etc.
10*a*. Fingers present.
10*b*. Number correct.
10*c*. Detail correct. Two dimensions.
10*d*. Thumb shown. Opposition.
10*e*. Hand shown.
11*a*. Arm joints. Shoulder or elbow.
11*b*. Leg joints. Knee, Hip or both.
12*a*. Proportion. Head. Not more than ½ nor less than ⅛.
12*b*. Proportion. Arms. Equal to or longer than trunk.
12*c*. Proportion. Legs. Equal to or less than vertical trunk.
12*d*. Proportion. Feet. More than vertical.
12*e*. Two dimensions. Arms and legs.
13. Heel.
14*a*. Coordination. Lines *A*.
14*b*. Coordination. Lines *B*.
14*c*. Coordination. Head. Strict.
14*d*. Coordination. Trunk.
14*e*. Coordination. Arms and legs.
14*f*. Coordination. Features. Profile preferred.
15*a*. Ear present.
15*b*. Ear detail.
16*a*. Eye detail. Brow. Lashes.
16*b*. Eye detail. Pupil.
16*c*. Eye detail. Shape.
16*d*. Eye detail. Glance.
17*a*. Chin and forehead shown.
17*b*. Chin and forehead, detail.
18*a*. Profile *A*. One error. Head trunk and feet.
18*b*. Profile *B*. No error.

TABLE II.—SHOWING PERCENTAGE OF FAILURE ON EACH ITEM FOR EACH GROUP

Item*	Post-encephalitis	Psychopathic personality	Borderline deficiency
1	0	0	0
2	4	0	0
3	13	8	7
4*a*	4	0	0
b	13	0	0
c	71	40	40
5*a*	13	8	0
b	21	23	27
6*a*	63	23	27
b	79	38	47
7*a*	0	8	0
b	4	0	0
c	13	0	0
d	79	69	80
e	88	69	67
8*a*	63	38	40
b	75	54	67
9*a*	42	31	7
b	58	46	7
c	58	54	33
d	75	69	20
e	79	69	40
10*a*	33	23	20
b	79	62	47
c	79	54	60
d	96	100	93
e	92	62	73
11*a*	66	62	60
b	54	15	27
12*a*	50	38	33
b	50	38	33
c	42	31	27
d	54	31	20
e	63	31	13
13	75	31	60
14*a*	87	85	80
b	100	100	100
c	96	85	53
d	75	69	47
e	71	69	47
f	92	62	73
15*a*	63	69	73
b	79	69	73
16*a*	75	54	53
b	66	69	33
c	79	77	86
d	96	100	93
17*a*	87	92	67
b	87	85	73
18*a*	92	100	80
b	92	100	93

For key to table see p. 144.

of nine months greater. Thus it can hardly be said that the groups were equated but if we bear these differences in mind certain conclusions can be made.

The sexes were nearly equally divided. Of the twenty-four encephalitis cases twelve were boys and twelve were girls. The ratios of boys to girls in the psychopathic personality and borderline groups were five to eight and ten to five respectively. Thus in a total of fifty-two cases, twenty-seven were boys and twenty-five were girls.

RESULTS

In Table II we have an item-by-item analysis of the drawings. The table indicates some significant differences in the drawings made by the three groups.

Goodenough has maintained that the drawings of mentally deficient children are similar in quality to the drawings of normals, the only difference being that the former are retarded and show the characteristics of younger children. If this generalization be true, then we are justified in taking the borderline cases as a control for our present comparisons. While it is true that the groups are not directly comparable, nevertheless it will be noted that the low scores made by the two abnormal groups are principally due to a large percentage of failure on particular items. Furthermore, had the post-encephalitis group been more nearly equated in life age with the control group, it is probable that the observed differences would have been even greater.

From an inspection of Table II we seem justified in concluding that drawings made by post-encephalitis children are characterized by failure to receive credit on the following items: 4*c*, 6*a*, 6*b*, 8*a*, 9*a*, 9*b*, 9*c*, 9*d*, 9*e*, 10*b*, 10*c*, 11*b*, 12*d*, 12*e*, 14*c*, 14*d*, and 17*b*. Drawings made by psychopathic children are in general similar to those made by mental deficiency cases but are distinguished from the latter by a larger percentage of failure on items 9*a*, 9*b*, 9*c*, 9*d*, 9*e*, 14*c*, 14*d*, 14*e*, 16*b*, 17*a*, and 17*b*. Item 13 seems to be quite significant since it appeared in a larger percentage of psychopathic drawings than in either of the other two groups.

It has been maintained[1] that drawings characterized by a larger amount of detail but comparatively few ideas (verbalist type) are an indication of psychopathy. It has also been maintained that individual responses, such as features which are inexplicable to anyone except to the children are also indications of psychopathy.

[1] Goodenough, F. L.: *Op. cit.*, p. 63.

TABLE III

Diagnosis	Verbalism	Individual responses
Post-enceyhalitis	1	3
Psychopathic	1	1
Borderline MD	1	

In the fifty-two drawings which were studied only three were of the "verbalist type" and only four drawings contained "individual" characteristics. In Table III we have these drawings tabulated according to diagnostic groups.

GOODENOUGH TABLE

	Numbers of drawings showing characteristics	
	Boys	Girls
Masculine characteristics:		
1. At least head and feet shown in profile, and in same direction	58	36
2. Some accessory characteristics present, as pipe, cane, umbrella, house or scenery	21	9
3. Trousers transparent	12	3
4. Heel present	53	37
5. Figure represented as walking or running	20	7
6. Arms reaching below knee	11	3
7. Necktie shown	25	14
Feminine characteristics:		
1. Nose represented only by two dots	7	28
2. Feet less than $\frac{1}{20}$ total body length	4	16
3. Eyes showing two or more of the following details: Brow, lashes, pupil, iris	1	11
4. Hair very smooth or neatly parted	13	34
5. "Cupid's bow" mouth	1	7
6. Cheeks shown	1	7
7. Trousers flaring at base	6	21
8. Head larger than trunk	9	17
9. Arm length not greater than head length	11	26
10. Curly hair	2	7
11. Legs not more than $\frac{1}{4}$ trunk length	2	12

From Goodenough: Measurement of Intelligence by Drawing. Copyright 1926, World Book Company, Publishers. Yonkers-on Hudson, New York.

Goodenough has determined that certain characteristics appear more frequently in the drawings of one sex than in the other. Her table based on one hundred drawings of each sex appears on page 147.

In order to arrive at some objective measure which would indicate clearly the relative degree of femininity or masculinity a group of drawings exhibited, the total frequency of masculine characteristics was divided by the total frequency of feminine characteristics. For the normal group taken from Goodenough's table this procedure gives a quotient for the boys of 3.51 and for the girls of .58. Thus as the quotient rises masuclinity is indicated and conversely as it decreases femininity is indicated.

This same procedure was employed with the three groups under investigation with the results tabulated in Table IV.

TABLE IV.—SHOWING MASCULINE-FEMININE QUOTIENTS OF CHILDREN'S DRAWINGS

	Normal	Post-encephalitis	Psychopathic personality	Borderline deficiency
Boys	3.51	.75	2.33	4.50
Girls	.58	1.50	.63	.75

It will be noted that post-encephalitis drawings seem to show a reversal of sexual characteristics while for the other two groups the trend is in the same direction as noted for normals. This finding seems to be in accord with Goodenough's statement that out of fourteen drawings by children who had been diagnosed psychopathic, seven exhibited reversal of sexual characteristics.

It has been said that the combination of mature and primitive characteristics in a single drawing may be evidence of psychopathic tendencies.[1] An attempt was made to check such a condition in the drawings made by the present groups.

While the general arrangement of items on the Goodenough scale is such that primitive items tend to be found among the first numbered, yet an inspection of the published curves showing the frequency of occurrence of each item at successive year intervals reveals that the arrangement of items does not progress evenly from primitive to mature characteristics.

[1] Goodenough, F. L.: *Op. cit.*, p. 63.

Accordingly, it was necessary to pick items whose curves were similar in points of origin and termination and whose characteristics were as nearly alike as possible. By this technique twenty items were paired as similar. They are listed in Table V.

We seem to be justified in concluding that since items are similar in their incidence at various year intervals in normal children, they are approximately equal so far as being rated primitive or mature is concerned. Furthermore, if the above hypothesis is correct concerning indications of psychopathy, we would expect the non-psychopaths to pass with approximately equal frequency any set of paired items. Likewise psychopaths as a group should exhibit a greater difference of success between any two paired items.

TABLE V.—SHOWING DIFFERENCE OF SUCCESS ON PAIRED ITEMS
(In Terms of Per Cent)

Items of similar maturity	Post-encephalitis	Psychopathic personality	Borderline deficiency
4*c* and 14*c*	25	31	13
6*a* and 17*a*	24	61	40
6*b* and 11*a*	8	25	13
9*c* and 14*f*	34	8	40
14*c* and 14*d*	21	16	6
2 and 7*a*	9	8	0
7*b* and 7*c*	66	0	0
7*c* and 15*b*	7	0	6
14*b* and 18*b*	8	0	7
16*c* and 17*b*	8	8	13
Total	210	157	138

In order to compile Table V it was necessary to compute the percentage of each group passing each of the items listed. The percentages of each of the items in a pair were subtracted giving the differences tabulated.

It will be noted that the sum of these differences for the post-encephalitis cases is greater than the sums for either of the other groups. While there are marked differences between psychopathic children and those diagnosed post-encephalitis, the latter are characterized by marked emotional instability, involving behavior tendencies similar to those found in psychopathic children. Usually the emotional instability is distinctly more abnormal than that noted in psychopaths.

Consequently, the findings in Table IV are in harmony with the hypothesis suggested by Goodenough, *i.e.* the most unstable group has the greatest difference of success on items of similar maturity while the most stable group has the smallest difference.

SUMMARY AND CONCLUSIONS

The drawings of fifty-two children with diagnoses of post-encephalitis, psychopathic personality and borderline mental deficiency were studied with the use of the Goodenough scale. These children were all committed to the Allentown State Hospital and were in the pre-adolescent or adolescent periods. On the basis of the statistical treatment outlined above, we are justified in making the following conclusions:

First, diagnostic differences appeared on particular items in the drawings made by the three groups.

Second, that a very small percentage of "verbalist" and "individual" responses appeared in the drawings.

Third, that reversal of sex characteristics appeared in the post-encephalitis drawings while the trend in the other two groups was similar to that found in normal children.

Fourth, that the combination of mature and primitive characteristics is found most frequently in those cases characterized by great emotional instability.

NOMOGRAM FOR DETERMINING VALIDITY OF TEST ITEMS

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In the Division of Educational Reference at Purdue University the validity of test items against the criterion of total score is conveniently and rapidly determined by means of the accompanying chart which is based upon the equation given by D. F. Votaw in his article "Graphical Determination of Probable Error in Validation of Test Items."[1] The chart given here utilizes the numbers of responses, thus making it unnecessary to calculate the proportions as Votaw requires. The equations may be variously expressed, one form of which is

$$p_1 = \frac{2p_2 + h^2 \pm \sqrt{(8h^2 + 4h^4)(p_2 - p_2^2) + h^4}}{2(1 + h^2)} \qquad (1)$$

and

$$h = \frac{0.6745k}{\sqrt{N}} \qquad (2)$$

where

p_1 = proportion of upper group answering item correctly,
p_2 = proportion of lower group answering item correctly,
N = number in the upper group or lower group (taken as twenty-seven per cent of the total in constructing the chart),[2]
k = minimum value of ratio of PE's for upper and lower group (taken as three for the chart given here).

The following substitutions have been made for the preparation of the accompanying chart:

$$p_1 = \frac{N_1}{N}, \qquad p_2 = \frac{N_2}{N}, \qquad R = \frac{p_1}{p_2} = \frac{N_1}{N_2}$$

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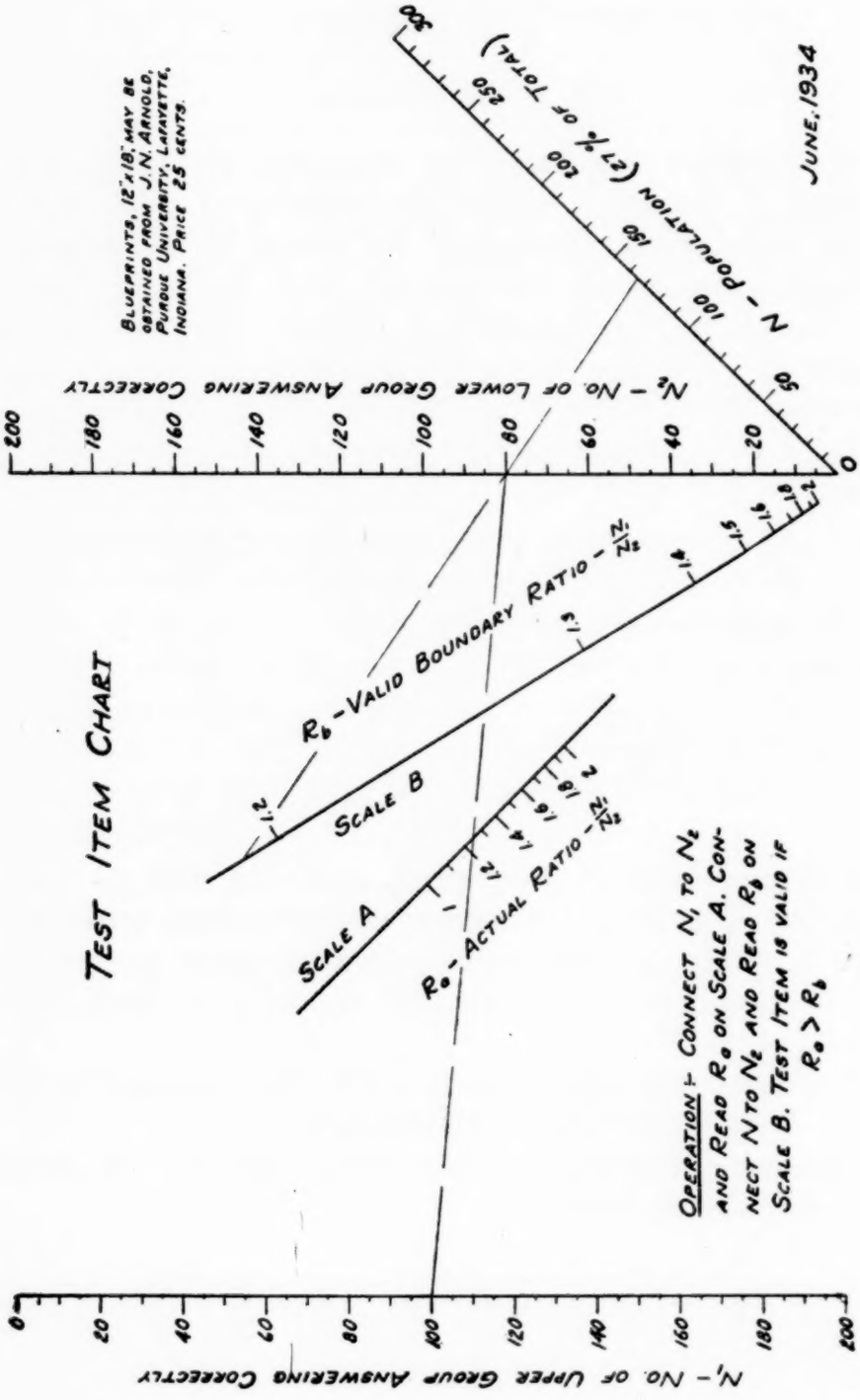
[1] *Journal of Educational Psychology*, December, 1933, pp. 681–685.

[2] Jensen, Milton B.: *Trait Differences Between Three Groups in Education.* (Unpublished Doctors Thesis, Stanford University, 1927), establishes twenty-seven per cent as the optimum, pp. 26–27.


TEST ITEM CHART
JUNE, 1934
BLUEPRINTS, 12"x18", MAY BE OBTAINED FROM J. N. ARNOLD, PURDUE UNIVERSITY, LAFAYETTE, INDIANA. PRICE 25 CENTS.
N - POPULATION (27% OF TOTAL)
N2 - No. OF LOWER GROUP ANSWERING CORRECTLY
N1 - No. OF UPPER GROUP ANSWERING CORRECTLY
Rb - VALID BOUNDARY RATIO - N1/N2
Ra - ACTUAL RATIO - N1/N2
SCALE A
SCALE B
OPERATION :- CONNECT N1 TO N2 AND READ Ra ON SCALE A. CONNECT N TO N2 AND READ Rb ON SCALE B. TEST ITEM IS VALID IF Ra > Rb

where

N_1 = number of upper group answering item correctly,

N_2 = number of lower group answering item correctly.

Equation (1) represents the boundary condition for validity, assuming that k is constant. If p_1 is greater than this boundary value, or if p_2 is less than the boundary value, the test item is valid. From this it is evident that if the actual value of their ratio, R, is greater than the boundary value, the item is valid. Therefore, the chart given here solves for the actual ratio, R_a, and for the boundary value, R_b; and if $R_a > R_b$ for a given question, it is valid.

As an example, an examination was given to a group of five hundred of the one hundred thirty-five papers, (twenty-seven per cent of the total), receiving the highest total scores, one hundred answered question one correctly and thirty-five answered it incorrectly. Of the one hundred thirty-five papers, (twenty-seven per cent of the total), receiving the lowest total scores, eighty answered the first question correctly and fifty-five gave incorrect answers. Is question one valid? In determining the validity by means of the chart we must know that $N = 135$, $N_1 = 100$, and $N_2 = 80$. Laying a straight edge across the scales for N_1 and N_2 we read $R_a = 1.25$ on Scale A. Shifting the position of the straight edge to pass through $N = 135$ and $N_2 = 80$ we read $R_b = 1.2^-$ on Scale B. Thus question one is valid since $1.25 > 1.2$.

NOTE ON THE SAMPLING ERROR OF THE MEDIAN

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A generally applicable formula for the sampling error of the median has been given by several authors.[1] It may be written in the following form:

$$\sigma_{Mdn} = \frac{i\sqrt{N}}{2f}$$

where i is the class-interval, f the number of observations in the class within which the median lies, and N the number in the whole sample. In a normal distribution, the above formula reduces to

$$\sigma_{Mdn} = \frac{1.2533\sigma}{\sqrt{N}}$$

Most textbooks in statistical method, however, ignore the first formula and give an appearance of universal validity to the second formula which is presented without mentioning its limitations.[2] Neither is the general formula necessarily made available in books which explicitly recognize the assumption of normal distribution in the derivation of the second formula.[3] But the use of the second formula in cases where the distribution is not normal usually leads to unnecessary inaccuracy and, if the distribution departs markedly from the normal, the error may be considerable. Worst of all, the second formula as usually presented creates an erroneous impression as if the median were of necessity less reliable than the mean, whereas there are leptokurtic distributions for which the median rather than the mean is the less influenced by fluctuations of sampling.

The writer has on hand some data in experimental sampling which will serve to verify the first formula and to show large errors of the second in cases of distinctly platykurtic or leptokurtic distributions. An ideal rectangular distribution of the ten single-digit figures and a

[1] Kelley, T. L.: *Statistical Method.* P. 90.
Rietz, H. L.: *Mathematical Statistics.* P. 135.
Yule, G. U.: *An Introduction to the Theory of Statistics.* P. 341.

[2] Garrett, H. E.: *Statistics in Education and Psychology.* P. 126.
McCall, W. A.: *How to Measure in Education.* P. 402.
Mills, F. C.: *Statistical Methods.* P. 556.
Odell, C. W.: *Educational Statistics.* P. 223.
Pearl, R.: *Introduction to Medical Biometry and Statistics.* P. 271.

[3] Holzinger, K. J.: *Statistical Methods for Students of Education.* P. 238.
Reitz, H. L. (Editor): *Handbook of Mathematical Statistics.* P. 77.

leptokurtic distribution of five thousand five hundred seventy-eight per cent price changes[1] were employed from which samples were drawn by running down the last digits in the cube root columns of *Barlow's Tables;* in the first case each figure by itself was taken as a sample, and in the second case four figures in succession were taken as a four-digit number to indicate which of the five thousand five hundred seventy-eight measures was to be taken, numbers exceeding five thousand

TABLE I.—STATISTICAL CONSTANTS DERIVED FROM THE IDEAL OR ORIGINAL DISTRIBUTION

Statistical constants	Rectangular distribution of ten single-digit figures	Leptokurtic distribution of five thousand five hundred seventy-eight per cent price changes
Mean	4.50	1.34
Median	4.50	.33
σ of distribution	2.87	13.3
σ_M for samples of twenty-five	.574	2.66
σ_{Mdn} for samples of twenty-five, normality not assumed	1.000	1.48
σ_{Mdn} for samples of twenty-five, normality assumed	.719	3.33

five hundred seventy-eight being naturally discarded. In all, twenty sets of twenty-five samples were drawn from each of the two given populations. The median, and also the mean, of each set were then computed. These are given in Table II, while the necessary constants for comparison derived from the ideal or original population are presented in Table I. A comparison of the root mean square errors of the sample medians given in the last row of Table II with the calculated standard errors in Table I very clearly shows that only the first formula is valid for these two types of distributions and that the second formula errs in underestimation for platykurtic, and overestimation in leptokurtic, distributions. Incidentally, it may be noted that the standard error of the mean as calculated by the usual formula seems to yield a

[1] The latter distribution was taken from Kelley, T. L.: *Statistical Method.* Pp. 25–26.

closer agreement with the observed root mean square error than in the case of the median, but the reliability of this difference is doubtful.

Educators and psychologists have sometimes preferred the median to the mean, with the reason that the former is subject to less influence of a few measures in the extreme. While this sort of intuitive judgment is often essentially sound, a statistical criterion would of course be

TABLE II.—MEANS AND MEDIANS OF SAMPLES OF TWENTY-FIVE

Number of sample	Rectangular distribution		Leptokurtic distribution	
	Mean	Median	Mean	Median
1	3.72	3	−3.36	−1.40
2	4.28	4	− .64	.33
3	3.48	3	3.84	1.25
4	4.96	6	1.44	−2.67
5	3.56	4	.80	.33
6	4.92	5	4.00	.75
7	4.80	5	1.60	− .33
8	4.08	4	6.24	5.50
9	3.60	3	6.88	1.33
10	5.04	5	.96	2.75
11	4.80	5	.16	1.00
12	3.68	3	−1.12	.50
13	3.72	3	− .48	.00
14	4.68	6	.00	.50
15	4.36	5	5.12	1.60
16	4.84	5	.48	.00
17	4.96	5	6.40	5.33
18	5.16	5	− .80	− .73
19	5.04	5	1.12	− .25
20	4.28	4	−1.60	− .20
True value.....	4.50	4.50	1.34	.33
Root mean square error...	.586	.975	2.84	1.95

more dependable. If we let i designate the class interval, f the number of observations in the class within which the median lies, N the number in the whole sample, and σ the standard deviation of the distribution, as before, the following ratio of the standard error of the median to that of the mean furnishes a convenient guide as to whether the mean or the median is the better measure of central tendency in a particular case:

$$\frac{\sigma_{Mdn}}{\sigma_M} = \frac{iN}{2f\sigma}$$

BOOK REVIEWS

BEN KARPMAN. *Case Studies in the Psychopathology of Crime, Vol. I.* Washington, D. C.: Mimeoform Press, 1933, pp. X + 1042.

In this book Dr. Karpman, psychotherapist at St. Elizabeths Hospital in Washington, D. C., presents five of the most detailed case studies about what he in his dedication to Dr. William A. White refers to as "our doubly unfortunate friends, the criminal insane." In each case study an attempt is made to understand the criminal individual through a thoroughgoing search for psychogenetic factors underlying his behavior. Source materials used in each case include official records, biographies, observations by fellow mates, letters and personal documents and follow-up reports. Each case study includes a discussion of diagnosis and interpretation and ends with an epitome, a sort of summary of the highpoints in the case. The appendix includes maps as an aid for following the descriptions of the itineraries made by the subjects, and an index.

The biographical materials used in this book are as comprehensive as they are because of the methods used. These methods are briefly as follows: The patient is asked to write his own story without any further suggestions on the part of the examiner; on the basis of the material obtained questions are made out, the answers to which are then incorporated in the original; this process is continued until the history is, in the opinion of the investigator, satisfactorily complete. For some cases interviewing, free association and other analytical techniques have also been used. Because the present volume is intended for a larger public the material is not obscured by many personal interpretations. A more intimate psychotherapeutic study of the same five cases the author plans to publish in a separate volume to be called *The Individual Criminal.*

The first case discussed by the author might be very roughly summarized as follows: A boy with a sensitive nature steals a horse. He later becomes a fugitive from home and develops a feeling of guilt about his having degraded his family. After other contributory but less significant acts he steals sacramental wine. After some more insignificant episodes he gets syphilis. In his own eyes he becomes a social outcast. His behavior, therefore, becomes an overcompensation for a sense of defeat. Similar psycho-social factors are described in the other case histories. Illustrative of contributing factors reported are inferior physical make-up, loss of a younger sister at the age of

six, unstable home, growing up emotionally starved in a drab environment, homosexual trends, education for criminality in a reformatory. Instructive are the vivid descriptions given of the reactions of the cases to such things as water cures and other forms of prison punishment. And interesting are the reactions of the criminals to treatment, education, reform and prevention of criminality. Typical are the following reactions of Oscar Fliegelmann, Case No. 1:

"I do not thing that the judge that sentenced me to prison gave a second's thought about whether I would come out of prison a more dangerous criminal than when I entered. But if I were to go back into the criminal game, I can truthfully say that I would be many times more dangerous than I was three years ago. Prisons serve their purpose for holding men and women in confinement, but they do not reform, and never will under the present system. They might better be classed as large factories for turning out first class criminals." . . . "I know how the law works, and I never look for a square deal from it." . . . "I would like to see the prisons throughout the country hand out education and character building to first timers, instead of trying to break what little spirit is left in them by torture, suffering, disappointment and other distress." . . . "I know that in my own case I have for years run more or less amuck through the lack of a full understanding of myself. But the psycho-therapy I have received has done me worlds of good. It has opened up a way to many of the unconscious elements in my life, so that now I can understand myself and use reason and logic and better judgment. I wish that other men who have gotten off the track could have a similar course."

Case No. 2 is described by the author as belonging to the class of drifters. This subject has a long history of restless wanderings, social maladaptation, many arrests and hospitalization, and drifts into crime as a matter of course. Case No. 3 is described as a homosexual male prostitute. Case No. 4 is described by the author as an instance of an individual whose background lacks criminal antecedents, who in the ordinary course of human events would probably not have been a criminal, who is drawn into crime by circumstances too powerful for his hysterical make-up to oppose. Case No. 5 is interpreted as an illustration of criminality developed as an emotionally conditioned reaction which at the proper time could have been corrected. All case studies are loaded with intimacies of life experiences of individuals who have, all things considered, done little hiding either in the description of life events or in their feeling reactions to them.

The make-up of the book makes it difficult to handle for reading purposes. The pages are big, the book is large, the printing not too clear, with more than the average number of spelling mistakes. Personally, the reviewer would have liked it better if the author had published one case study and the detailed psychogenetic interpretation that he plans to give it in his book on *The Individual Criminal*, than in having one book of case studies and another one interpreting the same case studies. This, however, is merely a criticism of the manner in which the materials were put out for public consumption. The material itself, because of its richness of detail and variety of approaches, should be of value to all interested in the crime problem as well as to students of criminology.

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